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Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	ki'lo
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'tĭ
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
A	ampere(s)	
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps=2.22×10^{12} dpm
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	3.527×10^{-2} ounces= 2.205×10^{-3} pounds
Hz	hertz	cycle per second
kVp	kilovolt peak	
m	meter(s)	39.4 inches=3.28 feet
m^3	cubic meter(s)	
mCi/ml^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
mi	mile(s)	
ml	milliliter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g
r/min	revolutions per minute	
s	second	
yr	year	

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RADIATION DATA AND REPORTS

Volume 15, Number 8, August 1974

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

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U.S. ENVIRONMENTAL PROTECTION AGENCY

Russell E. Train, Administrator

Reports

Calculations of Doses, Population Doses and Potential Health Effects Due to Atmospheric Releases of Radionuclides from U.S. Nuclear Power Reactors in 1972

Office of Radiation Programs,
Environmental Protection Agency [1]

Atmospheric emissions of radionuclides during 1972 reported by operators of 14 boiling water nuclear power reactors and 2 pressurized water nuclear power reactors in the United States were analyzed to calculate resulting doses in the general offsite environment. A sector-averaged diffusion equation, using facility generated onsite annual average meteorology, was used to propagate the emissions from the release point to a radius of 80 kilometers. In 1972, 4.88 megacuries of radioactivity were released to the atmosphere from 16 reactors on 13 sites. The resulting whole body population dose was calculated to be 1649 person-rem to a population of 29.2 million people. The potential health effects induced by external radiation from nuclear power plant emissions in 1972 were less than those induced by natural background and occupational radiation exposures.

This report presents the results of calculations of doses, population doses and potential health effects due to reported atmospheric emissions of radionuclides from operating nuclear power reactors in the United States in the year 1972. The calculational techniques used in the analysis were those discussed in a previous article (*1*). Radionuclide emissions were those reported by the U.S. Atomic Energy Commission (AEC) (*2*) or the facility operator directly. In a previous article, the emissions from 10 boiling water reactors (BWR) were analyzed. This article includes the analyses of four additional BWR's and two pressurized water reactors (PWR). All data herein refer to the year 1972.

For these calculations, a yearly average wind rose and a sector averaged diffusion equation were again used to propagate the emissions. Although this technique is applicable to the analysis of long-term, chronic releases typical in BWR operations (*3*), it is not appropriate for the analysis of sporadic or intermittent release cases. Because of the generally intermittent nature of PWR emissions, the calculated doses for PWR's have substantially greater uncertainties than those due to BWR emissions. Generally, doses due to PWR emissions were probably underestimated in some sectors and overestimated in others for 1972 and are more representative of the average yearly dose rate to be expected over a long period of time if yearly emission rates remain the same and are distributed in proportion to the yearly average wind rose. This approach is unavoidable if a yearly PWR analysis is made since facilities are not presently required to report meteorological conditions prevalent during periods of atmospheric releases.

Table 1 summarizes reported emissions by radionuclide used in the dose calculations. Total emissions were somewhat higher than that re-

[1] The principal investigators on this project are Mr. James A. Martin, Mrs. Mary Anne Culliton and Mr. Charles Robbins of the Surveillance Branch, Field Operations Division, Office of Radiation Programs, Environmental Protection Agency, Washington, D.C.

Table 1. Noble gas radionuclide emissions from selected U.S. nuclear power reactors, 1972

Radionuclide	Quantity (kCi)														
	Big Rock Point	Dresden Unit 1	Dresden Units 2 & 3	Humboldt Bay	Genoa	Millstone Unit 1	Monticello	Nine Mile Point	Oyster Creek	Pilgrim	Quad Cities 1 and 2	Vermont Yankee	R.E. Ginna Unit 1[a]	San Onofre Unit 1[b]
Krypton:														
83m	7.1			11.0										
85	13.0	35.0	35.0	15.0	2.2	41.4	54.0	40.3	65.5	0.18	11.7	6.0	0.045	0.04
85m	.44						6.8						1.2	.34
87	36.0	102.0	75.0	59.0	2.8	77.0	103.0	75.5	149.0	3.4	19.5	10.3		
88	29.0	147.0	63.0	54.0	3.0	116.0	140.0	113.0	200.0	3.0	17.4	6.1		
89	4.8			.3										
Xenon:														
131m	.0													3.8
133	.7			.6										1.14
133m	21.0	70.0	83.0	17.0	1.3	189.0	114.0	65.0	151.0	3.0	31.4	11.7	10.1	13.3
135	23.0	122.0	24.0	55.0	7.2									
135m	54.0	122.0	122.0	71.0	8.6	207.0	185.0	139.0	231.0	3.2	26.9			.55
137	8.8			1.9										
138	59.0	278.0	24.0	150.0	3.9	41.9	68.4	32.5	69.7		25.4	.5		
							< .17							
Argon-41														
Nitrogen-13	2.4													
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	259	876	426	435	29	672	665	465	866	13	132	35	11.3	19.2

[a] Specific radionuclide data from reference 2. Total activity released was somewhat greater due to the presence of very short (< 1 minute) half-lived radionuclides. Blanks indicate activity was not reported.
[b] Pressurized water reactors chosen because their emissions in 1972 were higher than all other reactors of this type; others are boiling water reactors.

ported for 1971. Several facilities operated throughout the whole of 1972 rather than only a small fraction of the year as in 1971, and new facilities were operational in 1972. Table 2 presents a facility operating summary, the maximum calculated cloud gamma doses to hypothetical individuals at the site boundary, and the calculated population doses within 80 kilometers (50 miles) of the facilities. Overall, total population dose in the general environment increased slightly in 1972 over 1971 due to somewhat higher emissions.

An interesting comparison between offsite and onsite population doses is presented in table 3. Occupational whole body population doses from BWR's exceeded general environmental cloud gamma population doses by more than a factor of 2.

BWR's contributed predominantly to offsite cloud gamma population doses. The PWR emissions data in table 4 indicate that the Ginna and San Onofre facilities accounted for over 80 percent of all PWR emissions. Assuming the same percentage for the PWR cloud gamma population dose, the total person-rem in table 3 is also the approximate total for all nuclear power plants in operation in 1972.

Tables 5 and 6 present the reported halogen releases and calculated inhalation (thyroid) doses and ground depositions. Inhalation doses were several orders of magnitude less than cloud gamma doses. As in the previous article, ingestion (thyroid) dose via the air-foliage-cow-milk-person pathway were not calculated due to the lack of data on release heights, chemical form of the iodine emissions, and uncertainties posed by recent results of field studies (*4*) which have not corroborated available pathway parameters. (These field studies are continuing in an attempt to resolve the discrepancies.) Figure 1 (*1*) indicates that ground depositions from small releases at or near ground level may predominate at distances within 1 kilometer of a site. This is well illustrated by a comparison of the Humboldt Bay and R. E. Ginna Unit 1 data in table 6. For these two cases, a small release at low height resulted in calculated ground level concentrations comparable to that from a much larger release at a higher altitude. (For these calculations, the

Table 2. Summary of energy generated, radionuclide emissions, dose and population dose for selected U.S. nuclear power reactors, 1972

Facility	Electrical energy generated [a] (GW(e)-year)[b]	Total gaseous emissions (kCi)	Population within 80 km (thousands)	Cloud gamma population dose (person-rem)	Maximum cloud gamma dose at fencepost[c]		
					Dose (mrem)	Distance (m)	Sector
Boiling water reactors:							
Big Rock Point	0.04	259	150	8	5.0	668	WSW
Dresden Unit 1	.13	876	6 140	503	13.0	1 219	SSE
Dresden Units 2 and 3	.93	426		177	2.0	1 767	S
Humboldt Bay	.04	435	100	57	67.0	254	SE
Genoa	.03	29	[d] 123	2	.8	805	S
Millstone Unit 1	.36	672	2 480	243	8.0	492	NE
Monticello	.41	665	2 600	315	30.0	704	SSE
Nine Mile Point	.37	465	930	40	11.0	335	S
Oyster Creek	.50	866	3 520	276	37.0	400	NE
Pilgrim	.10	13	4 660	6	.19	335	SSW
Quad Cities Units 1 and 2	.44	132	600	14	1.0	896	N
Vermont Yankee	.05	35	1 100	5	3.0	277	WSW
All boiling water reactors	3.40	4 850	22 400	1 646			
Pressurized water reactors:							
R.E. Ginna Unit 1	.28	11.3	1 100	1	<.4	All	All
San Onofre Unit 1	.32	19.2	5 700	2	<.5	All	All
Two pressurized water reactors	.60	30.5	6 800	3			
All 16 reactors	4.00	4 904	29 200	1 649			

[a] Assumes 0.3 electrical to thermal efficiency.
[b] 1 GW = 10^9 watts; GW(e)-yr = gigawatt (electric)-year.
[c] No credit given for building shielding or occupancy factors. Maximum dose to actual individuals was a factor of 2 to 3 lower.
[d] Within 40 km.

Table 3. Comparison of whole body population dose from gaseous emissions and occupational dose from selected reactors, United States, 1972

Facility	Whole body population dose [a] from gaseous emissions within 80 km (person-rem)	Occupational population dose [b] (person-rem)
Boiling water reactors:		
Big Rock Point	8	175
Dresden Units 1, 2, and 3	680	728
Humboldt Bay	57	254
Genoa	[c] 2	[d]
Millstone Unit 1	243	596
Monticello	315	60
Nine Mile Point	40	285
Oyster Creek	276	582
Pilgrim	6	16
Quad Cities Units 1 and 2	14	56
Vermont Yankee	5	[d]
All boiling water reactors	1 646	2 752
Pressurized water reactors:		
R. E. Ginna Unit 1	1	1 032
San Onofre Unit 1	2	257
Two pressurized water reactors	3	1 289
All 16 reactors	1 649	4 041

[a] Calculated using computer program AIREM.
[b] From testimony of Dr. Morton I. Goldman on behalf of the Consolidated Utility Group (Part 1), Nov. 9, 1973, at the AEC rulemaking hearing on effluents from light water-cooled nuclear power reactors, Docket No. RM-50-2.
[c] Within 40 km.
[d] Not available.

Table 4. PWR and HTGR releases and energy generation, 1972

Facility	Electrical energy generated (GW-yr)	Atmospheric radionuclide emissions (kCi)
Pressurized water reactors:		
San Onofre Unit 1	0.322	19.1
R. E. Ginna Unit 1	.277	11.4
Point Beach Units 1 and 2	.353	2.81
Haddam Neck	.490	.645
Indian Point Unit 1	.142	.543
Palisades	.216	.505
Robinson Unit 2	.50	.257
Yankee	.0733	.0183
Maine Yankee	.0528	.002
Surry Unit 1	.0421	<.001
Total	2.47	35.28
High temperature gas reactor:		
Peach Bottom Unit 1	.012	.058

elemental iodine (I_2) chemical form was assumed for *all* iodine releases; this may not be the case (*4*).)

A brief explanation for the difference in the magnitude of BWR and PWR emissions is in

Table 5. Halogen releases from selected U.S. nuclear power reactors, 1972

Facility	Effective release height [a] (m)	Quantity (Ci)		
		Iodine-131	Iodine-133	Iodine-135
Boiling water reactors:				
Big Rock Point	100	0.122	0.017	[b]
Dresden Unit 1	120	2.5	5.0	5.0
Dresden Units 2 and 3	200	5.0	10.0	10.0
Humboldt Bay	75	.4	1.7	[b]
Genoa	120	.693	.469	.012
Millstone Unit 1	150	1.23	[b]	[b]
Monticello	100	.576	1.16	2.26
Nine Mile Point	150	.893	.545	.279
Oyster Creek	150	6.26	7.04	5.82
Pilgrim	100	<.0266	.915	[b]
Quad Cities Units 1 and 2	200	.730	.603	.0703
Vermont Yankee	150	.171	.160	[b]
All boiling water reactors		18.6	27.61	23.4
Pressurized water reactors:				
R.E. Ginna Unit 1	10	.0335	.0015	[b]
San Onofre Unit 1	50	4.42×10^{-5}	[b]	[b]
Two pressurized water reactors		.0335	.0015	[b]
All 16 reactors		18.6	27.61	23.4

[a] Includes plume rise per reference *1*, except Quad Cities plum rise = 105 m and plume rise for Ginna and San Onofre = 0. Halogens presumed to be emitted from the stack at the effective release height.
[b] Emissions not reported.

order. The lower off-gas volumes which result from a typical PWR design permits these gases to be stored so that the shorter-lived radionuclides can decay. For BWR's, inplant holdup times are typically 1 hour or less. For PWR's, decay periods up to several months can be achieved under optimal conditions. This greater decay time contributes to the difference between PWR and BWR release magnitudes for plants with similar generating histories. A proposed regulation promulgated by the AEC (*5*) will require reductions in BWR gaseous emissions either by the installation of additional holdup capacity or by removal of the gaseous wastes. Thus, for future operation, doses from BWR releases may be expected to be substantially reduced. This may begin to occur as early as 1974.

The risk values given in the BEIR Report (*6*) were again used to estimate the number of potential health effects from external gamma radiation likely to occur in the populations residing within 80 km of operating nuclear power sta-

Table 6. Calculated inhalation (thyroid) doses and iodine-131 depositions, 1972

Facility	H_{eff} (m)	Iodine-131 released (Ci)	Adult inhalation (thyroid) population dose [a] within 80 km [a] (person-rem)	Maximum saturated ground activity [b]		
				(pCi/m³)	Distance (km)	Sector
Boiling water reactors:						
Big Rock Point	100	0.122	<0.005	1	1.2	ENE & SSW
Dresden Unit 1	120	2.5	1.34	20	2.4	SSE & NW
Dresden Units 2 and 3	200	5.0	1.94	15	2.4	SSE & NW
Humboldt Bay	75	.4	.03	37	.6	N
Genoa	150	.69	.04	10	2.4	N
Millstone Unit 1	150	1.23	.27	6	2.4	ENE
Monticello	100	.58	.22	11	1.2	SSE
Nine Mile Point	150	.89	.04	22	1.2	N
Oyster Creek	150	6.26	1.48	46	1.2	N
Pilgrim	100	<.03	0	<.5	All	All
Quad Cities Units 1 and 2	200	.73	.05	≤1	2.4	All
Vermont Yankee	150	.17	.03	4	.8	SSE
Pressurized water reactors:						
R.E.Ginna Unit 1	10	.0335	<.005	61	.5	NE
San Onofre Unit 1	50	4.4×10^{-5}	<.005	<0.01	All distances	
Total		18.6				

[a] Adult inhalation (thyroid) dose is less than 10 μrem in all cases.
[b] Assumes 1 cm/s deposition velocity, stack release, dry deposition only.

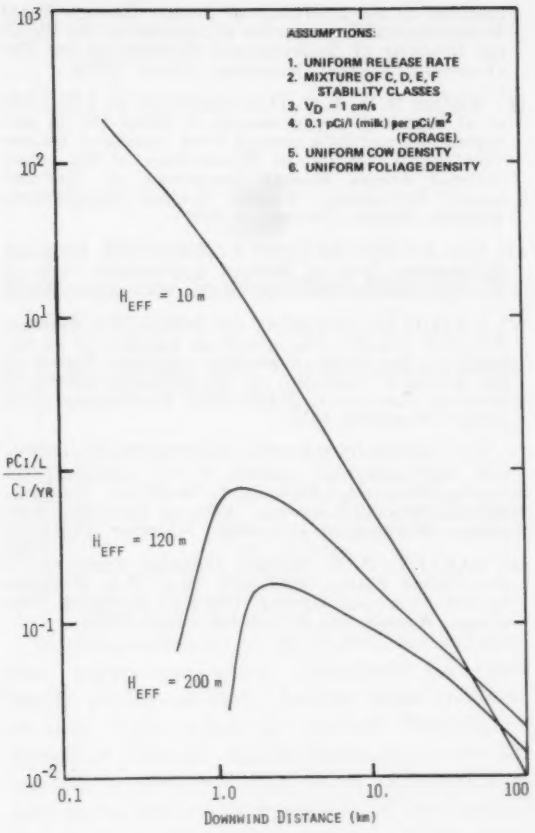

Figure 1. Iodine-131 concentration in milk in a typical high frequency sector (per curie released)

tions in 1972. Three sources of radiation were considered: natural background radiation, the external gamma radiation from atmospheric radionuclide reactor emissions, and occupational exposures. Potential health effects from radiation include fatal cancers, nonfatal cancers, and genetic effects in the approximate ratios 2:2:3, respectively. Somatic effects are assumed to occur within 30 years or so of exposure; genetic effects extend over several generations. The calculated health effects, based upon a risk factor of 7×10^{-4} health effects per person-rem (*7*) are presented in table 7. Uncertainties associated with calculations in this report are discussed in the previous article (*1*).

In summary, atmospheric emissions of radionuclides from 16 nuclear power facilities on 13 sites were analyzed to calculate resulting environmental doses for 1972. These facilities generated a total of 4000 megawatt-years of electrical energy during the year. The cloud gamma population doses to the populations within 80 km (50 miles) of these facilities, due to atmospheric emissions of 4904 kilocuries of radionuclides totaled 1649 person-rem in a population of 29.2 million. For the nuclear power industry as a whole, extrapolation of these data would indicate a total of about 1700 person-rem offsite cloud gamma population doses resulting from the production of 5880 megawatt-years of electrical energy by nuclear

Table 7. Calculated potential health effects, 1972

Facility	Population [a] (millions)	Electrical energy produced (GW(e)-yr)	Noble gas emissions (kCi)	Potential health effects		
				Natural [b] background	Cloud gamma	Occupational
Big Rock Point	0.15	0.04	235	9	0.0056	0.12
Dresden Units 1, 2 and 3	6.2	1.06	1 302	370	.48	.51
Humboldt Bay	.1	.04	435	5	.04	.18
Genoa (La Crosse)	.12	.03	29	8	.0014	
Millstone Unit 1	2.5	.36	672	160	.17	.42
Monticello	2.6	.41	665	140	.22	.042
Nine Mile Point	.9	.37	465	65	.028	.20
Oyster Creek	3.5	.50	866	160	.19	.41
Pilgrim Unit 1	4.7	.10	13	280	.0042	.011
Quad Cities Units 1 and 2	.6	.44	132	37	.11	.04
Vermont Yankee	1.1	.05	35	70	.0035	
R.E. Ginna Unit 1	1.2	.28	11.4	70	.0007	.72
San Onofre Unit 1	5.7	.32	19.1	290	.0014	.18

[a] Estimated populations within 80 km (50 miles) of the sites (40 km for Genoa).
[b] Natural background dose rate from reference *8*,

power facilities in 1972. Potential health effects induced by external radiation from nuclear power operations in 1972 were predominantly due to occupational exposures. Extrapolation of the population statistics for the sites considered, to include all sites, would indicate that between one-fifth and one-quarter of the U.S. population lived within 80 km (50 miles) of an operating nuclear power plant in 1972.

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Radioactivity in Brazilian Mineral Waters [1]

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Samples of mineral waters from various parts of Brazil were analyzed for their radium content. Radium-226 activity ranged from nondetectable to 94.1 pCi/liter, and radium-228 ranged from nondetectable to 152 pCi/liter.

In some countries of the world, bottled mineral waters are widely consumed for their health giving qualities. Among these qualities, at times, is the radioactive content. The label on Brazilian mineral waters normally gives the content in Mache Units.[6] It is of interest to note these waters as examples of the natural radioactive contamination of the environment.

These waters have been analyzed in the past (*1,2*) but the measurements have generally been based on the radon contained in the water. Advances in the radiochemical techniques in the past decade, however, justify a repetition of these measurements.

The samples were collected in plastic bottles at the source and shipped to Rio de Janeiro. Basically, the method of A. S. Goldin was then used (*3*). The sulphates of barium and radium are precipitated and collected onto a membrane filter after purification. The alpha activity is then counted using a plastic phosphor and phototube.

The activity is measured 30 days after precipitation and drying, and again after 60 days. The two measurements enable us to separate out the activities due to the two isotopes, radium-226 and radium-228. The data are presented in table 1.

Some of the rather active waters, from Caxambú (figure 1), were also bought in the commercial bottles and measured. It seems that an ion-exchange process removes the radium from the water and fixes it in the glass of the bottle before the water gets to the customer.

[1] This paper is based on work supported by the Brazilian National Institute of Technology, National Research Council, National Energy Commission, and the U.S. Atomic Energy Commission under Contract AT (11-1)-3437.

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[6] A Mache Unit corresponds to the measurement of the saturation current produced by emanation (expressed in absolute electrostatic units multiplied by 1000 occurring over a period of 1 hour from 1 liter of water. A Mache Unit is approximately equal to 0.364 nCi.

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Figure 1. Radioactivity in Brazilian mineral waters

Table 1. Radioactivity in Brazilian mineral waters

State, municipality	Source	Radium 226 (pCi/liter)	Radium-228 (pCi/liter)
Bahia:			
Caldas de Cipó	Caldas de Cipó	10.27	8.77
Camacarí	Dias D'Avila	.40	3.00
Cipó	Jórro	.28	.63
Coraçao de Maria	San Juliano	.50	1.16
Itaparica (Ilha de Itaparica)	Bica	1.95	1.87
Itapicurú	Itapicurú	.24	.49
Ceará:			
Fortaleza	Sao Geraldo	2.84	8.85
	Santa Ines	1.57	1.69
	Verdes Mares	25.91	15.03
Espírito Santo:			
Alegre	Conceiçao	ND	ND
Guaraparí	Mineral	.02	ND
Serra	Mineral	.10	1.15
Goias:			
Caldas Novas	Baths	.23	1.42
	Well near baths	.25	1.12
	Pool	.22	.58
	Poço do Padre	.23	.28
Caldas de Pirapitinga	Lake	.19	.21
	Lake drainage	.22	.23
	Well near river Pirapí	.18	.32
Caldas Velhas	Poço do Governador	.80	.91
	Well I	.91	1.65
	Well II	.99	.25
Pousada do Rio Quente	Ponte Japonesa:		
	Spring I	.35	1.03
	Spring II	.13	.28
	Spring III	.53	1.30
	Well no 4	.97	.56
Goiania, Chácara São José	Vindobona	ND	.25
Itapirapua, Fazenda			
Sao Joao	Sulfurosa fount	ND	.20
	Sulfurosa baths	.12	.46
Guanabara:			
Rio de Janeiro	Federal	.11	ND
	Nazaré	.18	ND
	Rica	.99	1.86
	Fontana	.11	ND
	Santa Cruz	ND	ND
Maranhao:			
Caxias	Veneza	.03	.38
Sao Luiz	Jaguarema	9.76	13.03
Mato Grosso:			
Barra do Garças	Hot spring	.20	ND
	Sao Sebastiao	.23	ND
General Carneiro	Hot spring	.16	.67
Palmeiras		.22	.38
Minas Gerais:			
Além Paraíba, paper factory	Well, 70 m deep	.12	
Além Paraíba	Fazenda Bom Retiro	.09	
Andradas	City supply	.07	
Araxá	Dona Beja	2.20	
Baependí	City supply	.02	
Belo Horizonte	City supply	.02	
Bicas	City supply	.03	
Caldas	City supply	.03	
Cambuquira	Marimbeiro I	1.66	
	Marimbeiro II	1.80	
	Marimbeiro III	1.57	
	Magnesiana	1.66	
	Gasosa a	1.91	
	Gasosa b	1.43	8.2
	Roxo Rodrigues	1.03	13.2
	Ferruginosa	5.02	10.4
	Souza Lima	3.33	10.1
Cataguazes	City supply	.03	
Caxambú	Mayrink I	1.58	3.8
	Mayrink II	2.53	18.2
	Mayrink III	2.08	4.2
	Viotti	2.21	2.7
	Dom Pedro II	3.91	7.0
	Dona Leopoldina	3.48	2.9
	Duque de Saxe	5.92	16.2
	Dona Isabel	18.7	5.1
	Conde d'Eu	18.9	7.3
	Beleza	87.8	118.8
	Venancio	94.1	102.8
	Nova	91.3	151.6
	Nascente Riacho Bengo	.05	
	Açude do Parque	ND	
Conceiçao do Rio Verde	Rio Verde	.14	
Contendas	Ferruginosa	.74	
	Magnesiana	1.09	
	Alcalina	.33	
	Gasosa forte	1.26	
	Bica do Pasto	.19	
	V. Marina	.22	
	Riacho do Parque	.05	

Table 1. Radioactivity in Brazilian mineral waters—continued

State, municipality	Source	Radium-226 (pCi/liter)	Radium-228 (pCi/liter)
Contendas	Well no 1 (16 m deep)	0.16	
	Well no 2 (6 m deep)	.12	
	Well no 3 (10 m deep)	.16	
	Well no 4 (18 m deep)	.13	
	Well no 5 (5 m deep)	.15	
	Well no 6 (5 m deep)	.09	
	Well no 7 (15 m deep)	.24	
	Well no 8 (7 m deep)	.09	
Dona Euzébia	Hélios	.02	
Ipuiuna	City supply	ND	
Itajubá	City supply	.02	
Jacutinga	São Clemente	.05	
Juiz de Fora	City supply	.03	
Lambarí	City supply	.03	
	No 1	3.02	ND
	No 2	2.86	ND
	No 3	3.25	
	No 4	1.28	
Leopoldina	City supply	.07	
Mar de Espanha	City supply	.66	
Montes Claros	City supply	.03	
Monte Sião	Natural	.05	
Montezuma	Bath I	.23	
	Bath II	.60	
Passo Quatro	City supply	.02	
	Julio Resnier	.06	
	Padre Manoel	.26	
Patrocínio	City supply	.02	
Piquete	City supply	.02	
Pocinhos do Rio Verde	Rio Verde	ND	
	São José	.02	
	Samaritana	.02	
	Amorosa	.35	
Poços de Caldas	City supply	ND	
	Sinhasinha	.06	
	Macacos	ND	
	Amores	ND	
	Santana	ND	
	Frayha	ND	
	15 de Novembro	ND	
	N.S. da Saúde	.08	
	Pedro Botelho	.09	
	Vivaldi	.17	
	Sto. Antonio	.08	
Route Rio-Bahia km 72	Well (40 m deep)	1.61	4.5
Salvaterra	Salvaterra	ND	
Samaritana	São Francisco	.17	1.12
Santa Rita de Sapucaí	City supply	.05	
São Lourenço	City supply	.11	
	Gasosa	.68	
	Magnesiana	1.91	
	Ferroginosa	6.47	5.0
	Alcalina	5.48	24.4
	Alcalina-Carbo-Sulphorous	9.32	18.4
	Alcalina, Vichy	11.18	25.2
São Luiz	Natural	.03	
	Agua Vita	.09	
Sarandí	Sarandí	.33	1.2
Tebas	Thebana	ND	
Thermópolis	Baths	.16	
Tiradentes, Hidrominas	Pool	.35	.69
	Well, in field	.03	
	City supply	.09	
Pará:			
Belém	N.S. dé Nazaré	.26	1.80
Salinas	Caranã	3.16	4.86
Paraíba:			
São Gonçalo	Brejo das Freiras	.36	.69
Paraná:			
Araucária	Prata de Casa	.12	ND
Bandeirantes	Yara	.02	ND
Campo Largo	Ouro Fino	.11	ND
Castro	Agua Quente	.26	ND
	Paraná	.06	.42
Cornélio Procópio	Agua Quente	.32	ND
Curitiba	City supply	ND	ND
	Aú	ND	ND
Fazenda Mendes	Jacú	ND	ND
Guarapuava	Santa Clara	ND	ND
	N. S. de Lourdes	ND	ND
	São Francisco	ND	ND
	Boa Vista	.05	ND
Jaguariava	Lambedor	ND	ND
Londrina	City supply	ND	ND
	Lon—Rita	.02	ND
Ponta Grossa	City supply	.04	.37
Pernambuco:			
Fazenda Nova		1.15	3.26
João Alfredo	Salgadinho	3.59	3.46
Quipapá	São Benedito	.06	.12
Recife	Santa Clara	.32	3.26

Table 1. Radioactivity in Brazilian mineral waters—continued

State, municipality	Source	Radium-226 (pCi/liter)	Radium-228 (pCi/liter)
Piauí:			
Cidade Jardim	Socopo	1.42	ND
Teresina	Agua Regina, Boqueirao	.62	
	York	4.13	1.67
Rio de Janeiro:			
Barra do Piraí	Ibitira	.09	ND
Campos	Bellieny	.04	
Itaboraí	Ferma	.09	
	Itaboraí	.03	
Itaperuna	Soledade, Sulphurous	.13	
	Soledade, Carbonated	.06	
	Cubatao	.03	
	Avahy	.07	
	Raposo	.14	
Magé	Santa Rita	.09	
Nova Friburgo	Boa Esperança	ND	
Nova Iguaçú	Ambaí	.09	
	Corcovado	.05	
	Sao Francisco de Paulo	.10	
Paraíba do Sul	City supply	.04	
Passa Tres	N. S. das Graças	.08	
Petrópolis	Petrópolis	.04	
	Casteliania	.35	
Salutaris	Maria Rita	.46	1.17
	Nilo Pecanha	.88	1.69
Sao Goncalo	Sao Gonçalo	.40	
Sto. António de Pádua	Farol	.05	
	Iodetada	.04	
Teresópolis	Teresópolis	.04	
Rio Grande do Norte:			
Extremoz	Santos Reis, Portinho	.72	1.05
Mossoró	Costa e Silva	4.88	ND
	Costa Calvacanti	6.16	.21
	Moacyr Vasconcelos	4.84	ND
	Paulo Godoy	1.37	ND
Rio Grande do Sul:			
Alegrete	Pampa	ND	ND
Frederico Westphalen	Prado	2.83	.22
Ijuí	Itaí	.32	.07
	Sulina	.60	.05
	Oswaldo Cruz	ND	.50
Pelotas	Serrana	ND	.15
Porto Alegre	Charrua	ND	.28
	Minuano	.57	.15
Santo Angelo	Nascente	3.74	.21
	Santa Tereza	ND	ND
Sao Leopoldo	Sempre Viva	.20	ND
Santa Catarina:			
Armazém	Santa Teresinha	.04	ND
Caldas de Cubatao	Santa Catarina	.18	.63
Chapecó	Chapecó	.45	ND
Florianópolis	City supply	ND	ND
Gravatá	Gravatal	.16	.62
Guarda—Tubarao	S. Anjo da Guarda	3.20	ND
	Rio Pouso	.35	ND
Palmitos	Ilha Redona	2.20	.50
Route BR-2, km 330	Sulfurosa	.14	.81
Santo Amaro	Caldas de Imperatriz	.08	ND
Urussanga	Sulfurosa, S. Pedro	3.61	5.25
	Thermal, S. Pedro	5.05	2.03
Sao Paulo:			
Aguas da Prata	Paiol	.04	
	Vilela	29.96	ND
	Vitória	.60	
	Nova	.36	
	Antiga	.16	
Amparo	Bocaina	1.07	4.84
Baurú	Santa Teresinha	.50	1.7
Bofete	Bofete	.76	
Campos do Jordao	Pinheiral	.05	
	Marisa	.21	
Cotia	Pluma	.20	
Embú	Jesuitas	.18	
Glicério	Sao Jorge	.02	
Indaiatuba	Santa Eliza	.27	
	Itaicí	.57	
Jacanga	Pocinho do Quilombo	.05	
Lindoia	Sao Benedito	.28	
	Tamoio	.41	
	Lindalia	.49	
Mairipora	Paulistinha	.07	
Mogi das Cruzes	Mogiana	.15	
	Aurea	.18	
Santos	Vila Mathias	.11	
	Drinking	.08	
	Biquinha	.10	
Ribeirao Pires	Serrania	.08	
	Pilar	.05	
Sao Paulo	Drinking	.08	
	Fontalis	.12	
	Gioconda	.03	
	Jaraguá 1	.33	

Table 1. Radioactivity in Brazilian mineral waters—continued

State, municipality	Source	Radium-226 (pCi/liter)	Radium-228 (pCi/liter)
Sao Paulo	Jaraguá 2	.09	
	Lausane	.09	
	Sao Pedro	.16	
	N. S. Lourdes	.10	
	Petrópolis	.09	
Sao Pedro	Almeida Sales	.27	
	Gioconda	.73	
	Juventude	.57	
Serra Negra	Rosário	.07	
	Sto. Agostinho	.09	
Sertaozinho	Palmital	.03	
	Sertaneja	ND	
Socorro	Pompeia	.08	
Taubate	Imaculada Conceiçao	.14	
	Sao Francisco	.39	

ND, nondetectable.

SECTION I. MILK AND FOOD

Milk Surveillance, March 1974

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption readily can be obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 65 sampling stations: 63 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks reporting presently in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior

Figure 1. Milk sampling networks in the Western Hemisphere

of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, first it was necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Research and Development Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been previously outlined (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the networks reported in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis fequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category				Experimental 2σ error (pCi/liter)
	Acceptable [a]	Warning level [b]	Unacceptable [c]	Total	
Iodine-131: (96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
(438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
Cesium-137: (53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
(295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
Strontium-89: (29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
(197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
Strontium-90: (32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
(150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and generally is increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below those practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range also has been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the United States data on radioactivity in milk in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are reported routinely in *Radiation Data and Reports.* The relationship between the PMN

Table 2. Concentrations of radionuclides in milk for March 1974 and 12-month period, April 1973 through March 1974

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES:						
Ala:	Montgomery [c]	P	NA	4	0	3
Alaska:	Palmer [c]	P	NA	4	0	1
Ariz:	Phoenix [c]	P	NA	0	0	0
Ark:	Little Rock [c]	P	NA	11	0	1
Calif:	Los Angeles [c]	P	NA	0	0	0
	Sacramento [c]	P	NA	1	11	1
	San Francisco [c]	P	NA	0	0	0
	Del Norte	P	0	10	0	4
	Fresno	P	0	1	0	1
	Humboldt	P	3	2	0	1
	Los Angeles	P	3	1	0	1
	Mendocino	P	2	2	0	1
	Sacramento	P	0	2	0	3
	San Diego	P	0	1	0	1
	Santa Clara	P	0	1	0	2
	Shasta	P	2	2	0	2
	Sonoma	P	2	2	0	3
Colo:	Denver [c]	P	NA	3	0	0
	East	R	NS	NA	NS	23
	Northeast	R	NS	NA	NS	0
	Northwest	R	NS	NA	NS	3
	South Central	R	NS	NS	NS	NS
	Southeast	R	NS	NA	NS	0
	Southwest	R	NS	NA	NS	0
	West	R	NS	NA	NS	0
Conn:	Hartford [c]	P	NA	4	0	2
	Central	P	NA		NA	
Del:	Wilmington [c]	P	NA	6	0	1
D.C:	Washington [c]	P	NA	3	0	0
Fla:	Tampa [c]	P	NA	4	28	25
	Central	R	5	5	59	29
	North	R	6	6	0	14
	Northeast	R	6	6	20	28
	Southeast	R	5	5	31	48
	Tampa Bay area	P	5	5	21	27
	West	R	8	8	0	8
Ga:	Atlanta [c]	P	NA	4	0	2
Hawaii:	Honolulu [c]	P	NA	0	0	0
Idaho:	Idaho Falls [c]	P	NA	3	0	0
Ill:	Chicago [c]	P	NA	5	0	0
Ind:	Indianapolis [c]	P	NA	5	13	3
	Central	P	4	5	0	5
	Northeast	P	5	5	0	10
	Northwest	P	7	7	0	8
	Southeast	P	6	6	0	7
	Southwest	P	9	7	0	5
Iowa:	Des Moines [c]	P	NA	4	0	0
	Des Moines	R	4	5	0	0
	Iowa City	R	6	5	0	0
	LeMars	R	3	4	0	0
	Little Cedar	P	7	6	0	0
Kans:	Wichita [c]	P	NA	5	0	1
	Coffeyville	P	6	6	0	7
	Dodge City	P	4	4	0	6
	Falls City, Nebr	R	3	6	0	8
	Hays	P	5	6	0	5
	Kansas City	P	6	5	0	5
	Topeka	P	5	6	10	6
Ky:	Louisville [c]	P	NA	5	0	1
La:	New Orleans [c]	P	NA	6	13	2
Maine:	Portland [c]	P	NA	4	14	13
Md:	Baltimore [c]	P	NA	6	0	3
Mass:	Boston [c]	P	NA	7	0	8
Mich:	Detroit [c]	P	NA	6	13	4
	Grand Rapids [c]	P	NA	7	0	1
	Bay City	P	11	11	0 (2)	2
	Charlevoix	P	8	9	0 (5)	2
	Detroit	P	6	8	0	0
	Grand Rapids	P	17	13	17	5
	Lansing	P	11	12	0 (2)	3
	Marquette	P	15	12	0	7
	Monroe	P	8	12	0 (2)	1
	South Haven	P	10	14	0 (4)	3
Minn:	Minneapolis [c]	P	NA	7	0	1
	Bemidji	P	NS	6	NS	0
	Duluth	P	12	16	0	16
	Fergus Falls	P	5	6	0	0
	Little Falls	P	12	16	0	25
	Mankato	P	5	5	0	0
	Marshall	P	NS	3	NS	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for March 1974 and 12-month period, April 1973 through March 1974—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi /liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
Minn:	Minneapolis	P	8	9	0	0
	Rochester	P	5	6	0	0
Miss:	Jackson [c]	P	NA	8	0	5
Mo:	Kansas City [c]	P	NA	4	0	0
	St. Louis [c]	P	NA	8	0	1
Mont:	Helena [c]	P	NA	2	0	0
Nebr:	Omaha [c]	P	NA	2	0	0
Nev:	Las Vegas [c]	P	NA	5	0	0
N.H:	Manchester [c]	P	NA	6	0	6
N.J:	Trenton [c]	P	NA	5	0	1
N. Mex:	Albuquerque [c]	P	NA	0	0	0
N.Y:	Buffalo [c]	P	NA	5	0	2
	New York City [c]	P	NA	4	0	2
	Syracuse [c]	P	NA	6	0	1
	Albany	P	4	4	0	0
	Buffalo	P	4	4	0	0
	Messena	P	8	7	0	0
	New York City	P	6	7	0	0
	Syracuse	P	4	5	0	0
N.C:	Charlotte [c]	P	NA	7	14	5
N. Dak:	Minot [c]	P	NA	6	0	0
Ohio:	Cincinnati [c]	P	NA	5	0	3
	Cleveland [c]	P	NA	6	0	2
Okla:	Oklahoma City [c]	P	NA	3	0	0
Oreg:	Portland [c]	P	NA	4	0	1
	Baker	P	NA			
	Coos Bay	P	NA			
	Eugene	P	NA			
	Medford	P	NA			
	Portland composite	P	NA			
	Portland local	P	NA			
	Redmond	P	NA			
	Tillamook	P	NA			
Pa:	Philadelphia [c]	P	NA	5	0	1
	Pittsburgh [c]	P	NA	9	0	2
	Dauphin	P	5	5	0	0
	Erie	P	5	6	0	0
	Philadelphia	P	10	5	0	0
	Pittsburgh	P	6	6	0	0
R.I:	Providence [c]	P	NA	4	0	3
S.C:	Charleston [c]	P	NA	5	15	7
	Anderson-01	R	7	7	0	0
	Anderson-02	R	5	5	0	0
	Chapin	R	NS	8	NS	9
	Clemson	R	NS	8	NS	10
	Columbia	R	NS	8	NS	9
	Fairfield	R	NS	7	NS	12
	Hartsville-02	R	NS	6	NS	10
	Hartsville-03	R	NS	15	NS	13
	Lee County	R	NS	7	NS	14
	Oconee County	R	NS	8	NS	7
	Pickens	R	7	7	12	9
	Williston	R	8	7	14	16
	Winnsboro	R	NS	7	NS	17
	York-01	R	NS	7	NS	6
	York-02	R	NS	5	NS	0
S. Dak:	Rapid City [c]	P	NA	6	0	1
Tenn:	Chattanooga [c]	P	NA	6	0	1
	Knoxville [c]	P	NA	0	0	0
	Memphis [c]	P	NA	6	0	2
	Chattanooga	P	6	7	0	5
	Clinton	R	10	7	0 (2)	6
	Fayetteville	R	13	8	0 (2)	6
	Kingston	R	11	8	0 (2)	3
	Knoxville	P	8	6	0	4
	Lawrenceburg	R	6	6	0 (2)	0
	Nashville	P	NS	5	NS	2
	Pulaski	R	8	6	0 (2)	2
	Sequoyah	R	NS	9	NS	6
Tex:	Austin [c]	P	NA	0	0	0
	Dallas [c]	P	NS	4	NS	0
Utah:	Salt Lake City [c]	P	NA	1	0	0
Vt:	Burlington [c]	P	NA	4	0	5
Va:	Norfolk [c]	P	NA	6	0	1
Wash:	Seattle [c]	P	NA	1	0	0
	Spokane [c]	P	NA	5	0	0
	Benton County	R	NS	0	NS	0
	Franklin County	R	3	0	0	0
	Longview	R	5	5	17	8
	Sandpoint, Idaho	R	3	5	0	1
	Skagit County	R	0	4	0	0
W. Va:	Charleston [c]	P	NA	7	0	2
Wisc:	Milwaukee [c]	P	NA	4	0	1
Wyo:	Laramie [c]	P	NA	1	0	1

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for March 1974 and 12-month period, April 1973 through March 1974—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
CANADA:						
Alberta:	Calgary	P	3	4	3	7
	Edmonton	P	4	5	9	10
British Columbia:	Vancouver	P	5	6	7	12
Manitoba:	Winnipeg	P	4	4	9	9
New Brunswick:	Moncton	P	6	7	9	9
Newfoundland:	St. John's	P	7	12	8	14
Nova Scotia:	Halifax	P	5	6	7	9
Ontario:	Ottawa	P	4	4	10	7
	Sault Ste. Marie	P	8	9	8	14
	Thunder Bay	P	7	6	10	10
	Toronto	P	3	4	NA	
	Windsor	P	2	2	1	5
Quebec:	Montreal	P	5	5	1	6
	Quebec	P	8	8	6	12
Saskatchewan:	Regina	P	5	4	6	6
	Saskatoon	P	5	5	3	6
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal [c]	P	NS	0	NS	0
Chile:	Santiago	P	0	0	0	0
Colombia:	Bogota	P	NS	1	NS	0
Ecuador:	Guayaquil	P	0	1	0	1
Jamaica:	Montego Bay	P	NS	2	NS	23
Puerto Rico:	San Juan [c]	P	NA	3	0	2
Venezuela:	Caracas	P	0	0	0	2
PMN network average [d]			NA	4	2	2

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a month period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

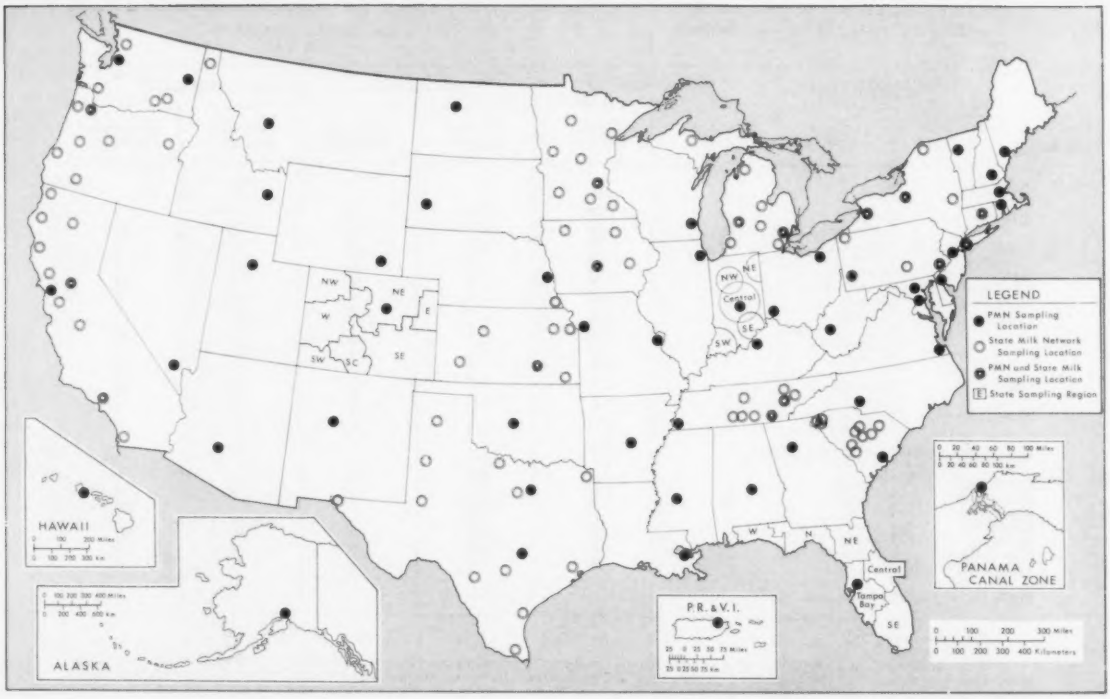

Figure 2. State and PMN milk sampling stations in the United States

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for March 1974 and the 12-month period, April 1973 to March 1974. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for March 1974 were below the respective practical reporting levels.

Strontium-90 monthly averages ranged from 0 to 17 pCi/liter in the United States for March 1974 and the highest 12-month average was 16 pCi/liter (Little Falls and Duluth, Minn.) representing 8.0 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 59 pCi/liter in the United States for March 1974, and the highest 12-month average was 48 pCi/liter (Southeast Florida) representing 1.3 percent of the value derived from the recommendations given in the Federal Radiation Council report.

The Office of Radiation Programs is in the process of modifying the milk program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Acknowledgment

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Radiologic Health Section
Environmental Control Component
California Department of Health

Radiation Protection Bureau
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Laboratory Division
Connecticut Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina Department of Health and Environmental Control

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Radiation Control Section
Division of Health
Washington Department of Social and Health Services

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(*2*) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) BARATTA, E. J. and F. E. KNOWLES, JR. Interlaboratory Study of iodine-131, cesium-137, strontium-89, and strontium-90 measurements in milk, June 1972, technical experiment 72 MKAQ–1. Analytical Quality Control Service, Office of Radiation Programs, EPA, Washington, D.C. 20460 (December 1972).

(*6*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

Food and Diet Surveillance

Efforts are being made by various Federal and States agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet	July 1971–December 1972	February 1974
Carbon-14 in Total Diet and Milk	1972–1973	November 1973
Strontium-90 in Tri-City Diets	1972	December 1973

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity for all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	1971 and 1972	November 1973
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
Florida	1970	April 1974
Interstate Carrier Drinking Water	1971	May 1972
Minnesota	July 1971–June 1972	March 1974
New York	January–December 1972	June 1974
North Carolina	1971	July 1974
Radiostrontium in Tap Water, *HASL*	January–December 1972	December 1973
Washington	July 1970–June 1971	August 1973

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(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in Kansas Surface Waters, January–December 1972

Radiation Control Section
Kansas State Department of Health

Monitoring of levels of radioactivity in the surface waters of Kansas is conducted by the Kansas State Department of Health, Radiation Control Section, in cooperation with the Kansas Water Quality Control Section and the U.S. Geological Survey. This surveillance program is important because of both the present and future potential use of Kansas surface waters for domestic, recreational, and industrial purposes.

Liter samples are collected every month at each location shown in figure 1. These samples are analyzed for gross alpha and beta radioactivity. In order to establish baseline data for the two power reactors which are located on the Missouri River in Nebraska, each Missouri River sample is gamma scanned for specific radionuclides. Specific radionuclide analyses are also performed on any other samples which indicate high gross alpha-beta activity. Radioactivity in these waters consists of the natural radioactivity picked up by flowing streams, radioactivity from sewage discharge into the streams, and some contribution by industrial waste. The final contributing factor to radioactivity content is fallout, particularly over large expanses of open water, such as reservoirs and lakes.

Analytical procedures

Radioactivity analyses are performed by the Kansas Radiation Laboratory. Measurements of gross alpha-plus-beta radioactivity are made with a windowless gas-flow proportional counter. Each sample is evaporated in an aluminum planchet, dried at 250° C, and then counted. Specific radionuclide analyses are determined by gamma spectroscopy or chemical separation.

Discussion

Table 1 shows the gross alpha and gross beta radioactivity in the total solids in Kansas surface waters from January through December 1972. These waters are used for domestic, industrial, and recreational purposes. The Arkansas River samples have consistently high activity which is attributed to uranium picked up from its drainage in Colorado.

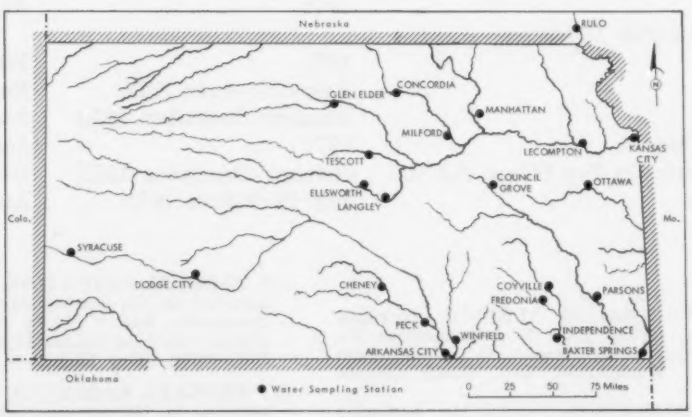

Figure 1. Kansas surface water sampling stations

Table 1. Gross radioactivity in Kansas surface waters, January-June 1972

Rivers	Sampling stations	Radioactivity concentration (pCi/liter)											
		January		February		March		April		May		June	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas	Arkansas City	8	11	14	5	NS	NS	3	12	3	6	5	25
	Dodge City	31	20	NS	NS	23	29	12	12	18	29	51	21
	Syracuse	56	15	34	34	22	6	22	0	75	0	16	0
Big Blue	Manhattan	2	22	2	33	2	9	2	23	1	0	NS	NS
Fall	Fredonia	0	8	4	1	7	0	3	27	1	0	5	31
Kansas	Lecompton	NS	NS	3	13	2	28	1	6	4	31	4	22
Marais des Cygnes	Ottawa	1	0	NS	NS	2	4	0	30	5	1	0	0
Missouri	Kansas City	NS	NS	5	0	5	45	5	28	4	9	NS	NS
	Rulo, Nebr	0	14	7	11	8	35	2	3	6	7	4	8
Neosho	Council Grove	NS	NS	NS	NS	2	5	1	8	3	9	3	0
	Parsons	NS	NS	6	10	2	32	0	8	0	24	2	9
Ninnescah	Cheney Reservoir	3	15	8	21	3	0	0	12	6	17	NS	NS
	Peck	2	6	8	10	3	21	0	7	3	26	1	0
Republican	Concordia	6	7	4	1	12	33	5	29	6	33	10	25
	Milford	7	24	6	0	6	9	2	15	6	53	4	25
Saline	Tescott	0	8	5	30	0	8	6	11	4	31	4	26
Smoky Hill	Ellsworth	0	32	10	0	9	78	11	28	NS	NS	14	14
	Langley	2	26	8	25	9	1	8	0	2	4	2	16
Solomon	Glen Elder	3	49	3	62	6	24	1	17	8	40	0	40
Spring	Baxter Springs	0	3	6	0	0	0	0	13	1	7	0	12
Verdigris	Coyville	0	9	0	0	0	15	0	16	1	18	1	17
	Independence	3	4	3	3	0	8	2	12	3	6	2	16
Walnut	Winfield	4	7	2	8	0	22	0	0	3	19	3	25

Table 1. Gross radioactivity in Kansas surface waters, July-December 1972—continued

Rivers	Sampling stations	Radioactivity concentration (pCi/liter)											
		July		August		September		October		November		December	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas	Arkansas City	0	13	0	13	0	25	4	15	5	5	0	0
	Dodge City	19	105	18	41	13	6	20	0	22	0	9	5
	Syracuse	25	93	NS	NS	24	33	29	19	0	22	0	0
Big Blue	Manhattan	3	26	1	12	2	0	2	8	0	0	3	46
Fall	Fredonia	3	15	0	0	0	18	0	5	3	12	0	0
Kansas	Lecompton	3	14	1	25	0	0	NS	NS	0	39	1	22
Marais des Cygnes	Ottawa	2	15	1	19	0	0	NS	NS	3	8	2	34
Missouri	Kansas City	NS	NS	3	30	4	27	1	0	8	0	NS	NS
	Rulo, Nebr	3	32	0	0	5	29	0	0	1	5	NS	NS
Neosho	Council Grove	3	7	5	1	0	6	1	7	2	3	2	0
	Parsons	0	5	0	0	NS	NS	0	17	3	13	0	19
Ninnescah	Cheney Reservoir	3	9	1	0	2	1	0	0	1	8	3	0
	Peck	0	30	0	1	0	16	0	0	0	0	2	0
Republican	Concordia	12	28	11	30	8	25	4	15	0	11	3	0
	Milford	4	21	5	9	2	19	2	0	3	17	4	9
Saline	Tescott	0	30	1	7	0	0	0	0	0	2	1	30
Smoky Hill	Ellsworth	0	50	3	14	2	26	0	0	0	0	0	0
	Langley	0	0	1	5	5	5	0	11	1	9	2	0
Solomon	Glen Elder	2	56	2	45	1	44	3	18	2	17	0	0
Spring	Baxter Springs	NS	NS	NS	NS	4	5	NS	NS	1	0	NS	NS
Verdigris	Coyville	0	21	1	0	0	9	0	0	0	0	0	0
	Independence	1	21	0	11	2	0	0	0	0	0	2	0
Walnut	Winfield	0	15	1	19	4	0	0	0	0	0	2	2

NS, no sample.

Previous coverage in *Radiation Data and Reports:*

Period	Issue
January–December 1971	February 1973

ERAMS Surface and Drinking Water Components January–March 1974

Office of Radiation Programs
Environmental Protection Agency

The Environmental Radiation Ambient Monitoring System (ERAMS), which began in July 1973, was developed from previously operating radiation monitoring networks to form a single monitoring system which is more responsive to current and projected sources of environmental radiation.

Present network

The ERAMS Surface and Drinking Water Components are an expansion of the previous Tritium Surveillance System which was operated by the Office of Radiation Programs from 1970 through June 1973. The Drinking Water Component consists of 76 quarterly drinking water samples taken from major population centers and selected nuclear facility environs (figure 1). The analyses include (a) tritium on a quarterly basis, (b) gamma scan, gross alpha and gross beta radioactive measurements annually with radium-226 and strontium-90 measurements if the gross alpha or gross beta radioactivity exceed 3 or 10 pCi/liter, respectively, and (c) an annual composite for plutonium-238 and -239 on 19 selected sampling locations. The Surface Water Component consists of 55 quarterly surface water samples downstream from nuclear facilities or at a background station (figure 2). The location of the sampling sites was based on all nuclear facilities that were operating, being constructed, or planned through 1976. Tritium analyses are performed quarterly and gamma scans annually. In addition to these components of ERAMS, precipitation samples will be collected at 19 selected locations (figure 1) and tritium measurements

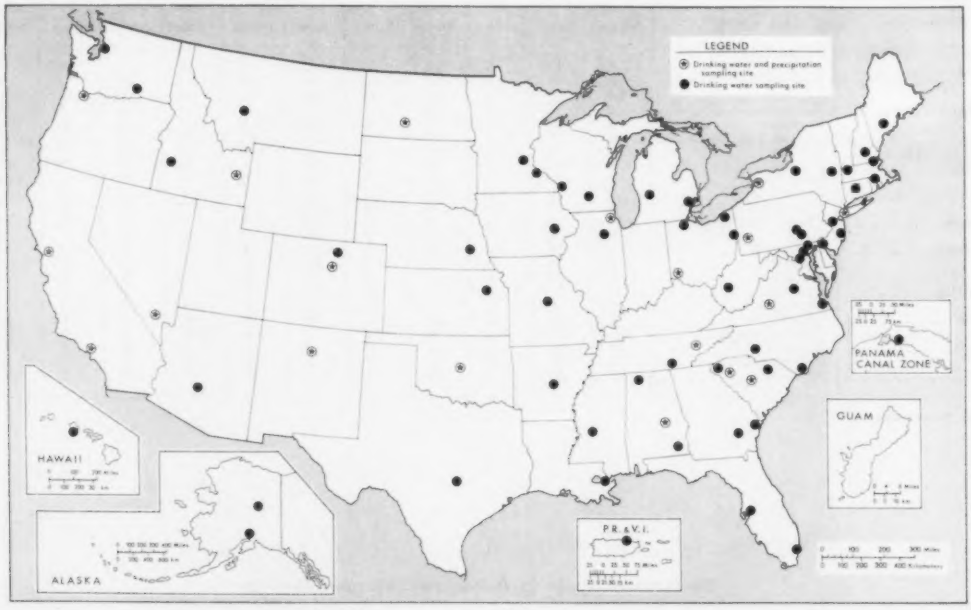

Figure 1. ERAMS drinking water component and precipiation sampling locations

are performed on the monthly composite from each station. These 19 locations correspond to air and drinking water sampling locations selected for plutonium analyses. Plutonium-238 and -239 analyses are performed annually on precipitation samples collected in April when elevated levels of rainfall are expected.

Results and discussion

Table 1 presents the tritium concentrations in drinking water at the Drinking Water Component stations for January–March 1974. The average tritium concentration was 0.2 nCi/liter.

In previous articles on the Tritium Surveillance System, the reported dose equivalents from tritium in body water have been based on a relationship derived by Moghissi and Porter (*1*). Their relationship assumed a quality factor of 1.7 for tritium beta rays based on a 1966 ICRP recommendation (*2*). Recently, the NCRP has recommended a quality factor of 1 for tritium beta rays (*3*) and this recommendation has been adopted for this and subsequent reports. Following the notation adopted by the ICRU (*4*) substitution of a quality factor of 1 in Moghissi and Porter calculations yields:

$$\dot{H}\ (\text{mrem/year}) = 0.1\ C\ (\text{nCi/liter})$$

Where $\dot{H}$ is the dose equivalent rate and C represents the tritium concentration in body water in nCi/liter.

It can be assumed for the purpose of calculating dose to members of the population that if the concentration of tritium in all water taken into the body is equal to that found in drinking water and also if that the specific activity of tritium in the body is essentially the same as that in the drinking water, then the radiation dose may be estimated.

The highest individual concentration of tritium observed in drinking water was 3.1 nCi/liter during the fourth quarter. This corresponds to a dose of 0.3 mrem/a.

The tritium concentrations for the Surface Water Component samples are given in table 2. The highest tritium concentration was 4.9 nCi/

Table 1. ERAMS Drinking Water Component, January-March 1974

Location		Date collected (1974)	Tritium concentration [a] (nCi/liter ± 2σ)[b]
Ala:	Dothan	1/3	0
	Montgomery	1/2	0
	Muscle Shoals	1/8	0
Alaska:	Anchorage	NS	
	Fairbanks	1/17	.5
Ark:	Little Rock	1/2	0
Calif:	Berkeley	1/2	.2
	Los Angeles	1/2	0
C.Z:	Ancon	1/21	.5
Colo:	Denver	1/31	.5
	Platteville	3/6	.9
Conn:	Hartford	1/2	0
Del:	Wilmington	1/22	.3
D.C:	Washington	2/11	0
Fla:	Miami	1/2	0
	Tampa	1/2	0
Ga:	Baxley	NS	
	Savannah	1/28	3.1 ± 0.3
Hawaii:	Honolulu	1/11	0
Idaho:	Boise	1/17	.3
	Idaho Falls	1/11	.3
Ill:	Chicago	1/17	1.0
	Morris	1/21	0
Iowa:	Palo	NS	
Kans:	Topeka	1/7	0
La:	New Orleans	1/30	.2
Maine:	Augusta	1/3	.2
Md:	Baltimore	2/28	0
	Conowingo	1/29	0
Mass:	Lawrence	1/2	0
	Rowe	1/21	.3
Mich:	Detroit	1/3	.4
	Grand Rapids	1/8	.3
Minn:	Minneapolis	1/9	.4
	Red Wing	1/10	0
Miss:	Jackson	1/2	0
Mo:	Jefferson City	1/10	0
Mont:	Helena	1/8	.3
Nebr:	Lincoln	1/11	.2
Nev:	Las Vegas	2/27	.8
N.H:	Concord	1/2	0
N.J:	Trenton	2/21	0
	Waretown	2/20	0
N. Mex:	Santa Fe	1/15	.5
N.Y:	Albany	1/7	0
	Buffalo	1/2	.3
	New York City	1/31	.3
	Syracuse	1/29	.6
N.C:	Charlotte	1/2	0
	Wilmington	1/21	0
N. Dak:	Bismarck	1/2	.5
Ohio:	Cincinnati	1/9	0
	East Liverpool	3/21	.4
	Painesville	1/14	0
	Toledo	NS	
Okla:	Oklahoma City	1/3	0
Oreg:	Portland	1/8	0
Pa:	Columbia	1/29	0
	Harrisburg	1/9	0
	Pittsburgh	3/21	.4
P.R:	San Juan	2/1	0
R. I:	Providence	1/2	.2
S. C:	Anderson	1/16	.3
	Columbia	1/2	0
	Hartsville	1/30	0
	Seneca	1/16	.2
Tenn:	Chattanooga	1/3	.5
	Knoxville	1/18	.4
Tex:	Austin	1/7	0
Va:	Doswell	1/7	0
	Lynchburg	1/3	0
	Norfolk	2/22	.2
Wash:	Richland	NS	
	Seattle	1/2	.2
Wisc:	Genoa	1/3	0
	Madison	1/2	0
Average			0.2

[a] The minimum detection limit for all samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

Table 2. ERAMS Surface Water Component, January-March 1974

Location		Water source	Collection date (1974)	Concentration[a] (nCi/liter $\pm 2\sigma$)[b]	Facility
Ala:	Decatur	Tennessee River	1/ 7	0.3	Browns Ferry, Sequoyah & Oak Ridge
	Gordon	Chattahoochie River	1/ 3	.3	Joseph M. Farley
Ark:	Little Rock	Arkansas River	1/14	0	Arkansas Nuclear One
Calif:	Clay Station	Folsom S. Canal	3/20	.2	Rancho Seco
	Diablo Canyon	Pacific Ocean	1/ 6	0	Diablo Canyon
	Eureka	Humboldt Bay	2/28	4.9 ± 0.3	Humboldt Bay
	San Onofre	Pacific Ocean	3/ 4	0	San Onofre
Colo:	Greely	South Platte River	3/ 6	.6	Fort St. Vrain
Conn:	East Haddam	Connecticut River	1/18	.2	Haddam Neck & Vermont Yankee
	Waterford	Long Island Sound	1/21	.3	Millstone
Fla:	Crystal River	Gulf of Mexico	1/31	0	Crystal River
	Ft. Pierce	Atlantic Ocean	1/ 7	0	St. Lucie
	Homestead	Biscayne Bay	1/ 8	.4	Turkey Point
Ga:	Baxley	Altamaha River	NS		Edwin T. Hatch
Idaho:	Buhl	Snake River	1/22	.3	National Reactor Testing Station
Ill:	Moline	Mississippi River	1/ 2	.3	Quad-Cities, Genoa, Prairie Island & Monticello
	Morris	Illinois River	1/21	.3	Dresden & Argonne
	Zion	Lake Michigan	1/ 4	.2	Zion
Iowa:	Palo	Cedar River	NS		Duane Arnold
La:	New Orleans	Mississippi River	1/ 3	0	(Several)
Maine:	Wiscasset	Montseway Bay	1/ 3	0	Maine Yankee
Md:	Conowingo	Susquehanna River	1/ 8	0	Peach Bottom & Three Mile Island
	Lusby	Chesapeake Bay	1/ 8	0	Calvert Cliffs
Mass:	Plymouth	Plymouth Bay	1/ 2	0	Pilgrim
	Rowe	Deerfield River	1/22	0	Yankee
Mich:	Bridgman	Lake Michigan	1/ 1	.3	Donald C. Cook
	Charlevoix	Lake Michigan	1/ 6	.2	Big Rock Point
	Monroe	Lake Erie	1/ 1	.4	Enrico Fermi
	South Haven	Lake Michigan	1/ 1	0	Palisades
Minn:	Monticello	Mississippi River	1/17	.7	Monticello
	Red Wing	Mississippi River	1/10	0	Prairie Island & Monticello
Nebr:	Rulo	Missouri River	2/18	.5	Fort Calhoun & Cooper
Nev:	Boulder City	Colorado River	1/ 7	.7	Background
N.J:	Bayside	Delaware River	NS		Salem
	Oyster Creek	Toms River	2/20	0	Oyster Creek
N.Y:	Ossining	Hudson River	1/ 7	0	Indian Point
	Oswego	Lake Ontario	1/ 2	.4	Nine Mile Point, James A. Fitzpatrick & R. E. Ginna
	Poughkeepsie	Hudson River	1/ 2	0	Background
N.C:	Charlotte	Catawba River	1/ 2	.3	Wm. B. McGuire
	Southport	Atlantic Ocean	1/22	0	Brunswick
Ohio:	Oak Harbor	Lake Erie	NS		Davis-Besse
Oreg:	Westport	Columbia River	NS		Trojan & Hanford
S.C:	Allendale	Savannah River	1/31	4.0	Savannah River Plant & Oconee
	Hartsville	Lake Robinson	1/30	$3.2 \pm .3$	H. B. Robinson
Tenn:	Daisy	Tennessee River	2/13	.4	Sequoyah & Oak Ridge
	Kingston	Clinch River	1/17	1.1	Oak Ridge
Tex:	El Paso	Rio Grande	1/ 2	.3	Los Alamos
Vt:	Vernon	Connecticut River	1/ 7	.2	Vermont Yankee
Va:	Mineral	North Anna River	1/15	.3	North Anna
	Newport News	James River	1/28	0	Surry
Wash:	Northport	Columbia River	1/29	.5	Background
	Richland	Columbia River	1/ 2	.4	Hanford
W. Va:	Wheeling	Ohio River	1/ 3	0	Shippingport & Beaver Valley
Wisc:	Two Creeks	Lake Michigan	1/ 7	.3	Point Beach & Kewaunee
	Victory	Mississippi River	1/ 4	.2	Genoa, Prairie Island & Monticello
Average				0.5	

[a] The minimum detection limit for all samples is 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

liter for the quarter. Assuming that the specific activity of tritium in the body is essentially the same as that in surface water, this concentration corresponds to a dose of 0.5 mrem/a.

The monthly analyses for tritium in precipitation samples at the selected stations are shown in table 3.

Other coverage in *Radiation Data and Reports:*

Period	Issue
January–March 1973	July 1973
April–June 1973	October 1973
July–September 1973	May 1974
October–December 1973	June 1974

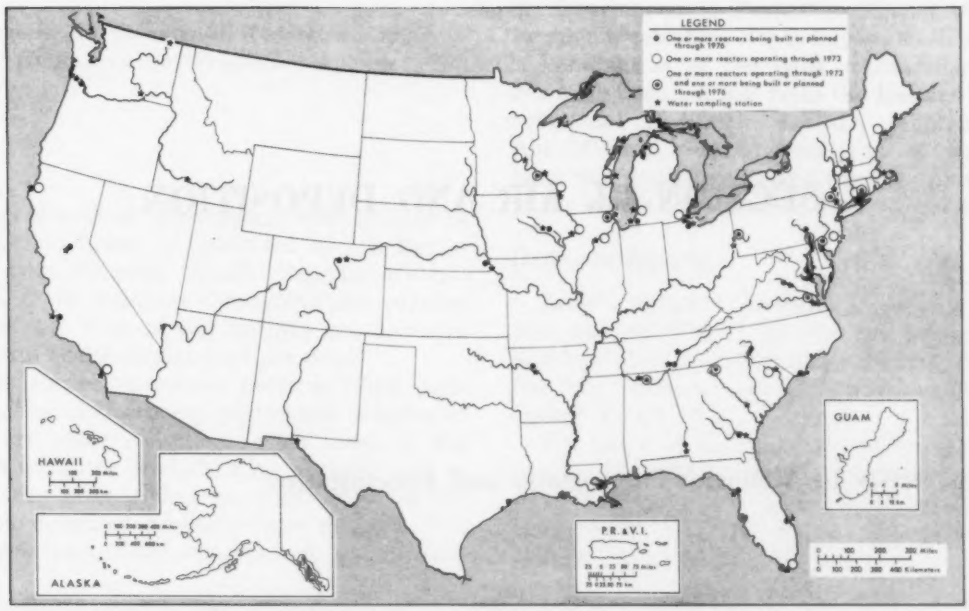

Figure 2. ERAMS surface water component sampling stations

Table 3. Tritium concentration in precipitation, January-March 1974

Location		Tritium concentration [a] (nCi/liter ± 2σ)		
		January	February	March
Ala:	Montgomery	0.4	0.7	0.3
Calif:	Berkeley	0	0	0
	Los Angeles	NS	NS	NS
Colo:	Denver	.2	.9	.4
Idaho:	Idaho Falls	0	0	.3
Ill:	Chicago	NS	NS	NS
Nev:	Las Vegas	NS	0	.2
N. Mex:	Santa Fe	0	NS	.3
N.Y:	Buffalo	0	.3	.3
	New York City	NS	NS	NS
N. Dak:	Bismarck	0	0	.5
Ohio:	Cincinnati	NS	NS	NS
Okla:	Oklahoma City	NS	NS	NS
Oreg:	Portland	NS	NS	NS
Pa:	Pittsburgh	NS	NS	NS
S.C:	Anderson	NS	NS	NS
	Columbia	.4	.3	.5
Tenn:	Knoxville	NS	NS	NS
Va:	Lynchburg	NS	NS	NS

[a] The minimum detection limit for these samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero. The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.
NS, no sample.

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were covered previously in *Radiation Data and Reports.*

Network	Period	Issue
Fallout in the United States and other areas, HASL	1971	August 1973
Krypton-85 in air	July 1970–1972	March 1974
Mexican air monitoring program	July–December 1973	May 1974
Plutonium in airborne particulates	April–June 1973	June 1974

1. Radiation Alert Network March 1974

Eastern Environmental Radiation Facility
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN). Samples are collected at 68 locations throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples are sent to the Eastern Environmental Radiation Facility for further analysis. All field estimate results are reported to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily measurements is available upon request from the Eastern Environmental Radiation Facility, Montgomery, Ala. 36109. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate and laboratory techniques during March 1974.

The Office of Radiation Programs is in the process of modifying the air program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, March 1974

Station location [a]	Number of samples	Gross beta radioactivity (pCi/m³)						Precipitation	
		5-hour field estimate			Laboratory measurement			Laboratory estimate of deposition	
		Maximum	Minimum	Average [b]	Maximum	Minimum	Average [b]	Depth (mm)	Total deposition (nCi/m²)
Ala: Montgomery	9	1	0	1	0.15	0.04	0.10	51	0.76
Alaska: Anchorage	1	0	0	0	.07	.07	.07		
Calif: Berkeley	9	0	0	0	.15	.04	.08	33	.18
Los Angeles	9	1	0	1	.36	.08	.15		
Colo: Denver	9	2	1	1	.40	.16	.25	15	.59
Idaho: Idaho Falls	8				.19	.06	.12	42	1.23
Ind: Indianapolis	8	0	0	0	.14	.06	.09		
Nev: Las Vegas	8	2	1	1	.27	.11	.19	8	.06
N. Mex: Santa Fe	4	1	0	1	.30	.12	.21	9	.39
N.Y: Buffalo	9	0	0	0	.17	.08	.10	1	.02
N. Dak: Bismarck	9	1	0	1	.14	.06	.08	6	.08
Ohio: Columbus	5	1	0	0	.13	.08	.11		
Okla: Oklahoma City	5	1	0	1	.18	.08	.11		
Oreg: Portland	21	0	0	0	.15	.02	.07		
Pa: Harrisburg	19	1	0	0	.20	.04	.08		
S.C: Columbia	9	1	0	1	.20	.06	.13	30	.64
Network summary	142	2	0	1	0.40	0.02	0.12	22	0.44

[a] The remaining stations are on standby status.
[b] The monthly average is calculated by weighting the estimates of individual air samples with length of sampling period.

2. Air Surveillance Network March 1974

National Environmental Research Center—Las Vegas
Environmental Protection Agency

The Air Surveillance Network,[1] operated by the National Environmental Research Center —Las Vegas (NERC-LV), consists of 49 active and 72 standby sampling stations located in 21 western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged after periods generally ranging from 48 to 72 hours. All samples are mailed to the NERC-LV unless special retrieval is arranged at selected locations in response to known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports*.

Table 2 presents the average gross beta concentrations in air for each of the network stations. The minimum reporting concentration for gross beta activity is 0.1 pCi/m³. For reporting purposes, concentrations less than 1.0 pCi/m³ are reported to one significant figure, and those equal to or greater than 1.0 pCi/m³ are reported to two significant figures. For averaging purposes individual concentrations values less than the minimum detectable concentration (~0.03 pCi/m³ for a 700 m³ sample) are set equal to the minimum detectable concentration (MDC). Reporting an drounding-off conventions are as follows:

[1] This network is operated under a Memorandum of Understanding (No. AT 26-1)-539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

Concentration (pCi/m^3)	Reported value of concentration above MDC (pCi/m^3)	Reported value of concentration below MDC (pCi/m^3)
<0.05	<0.1	<0.1
≥ 0.05, <0.15	0.1	<0.1
≥ 0.15	As calculated and rounded	< calculated MDC

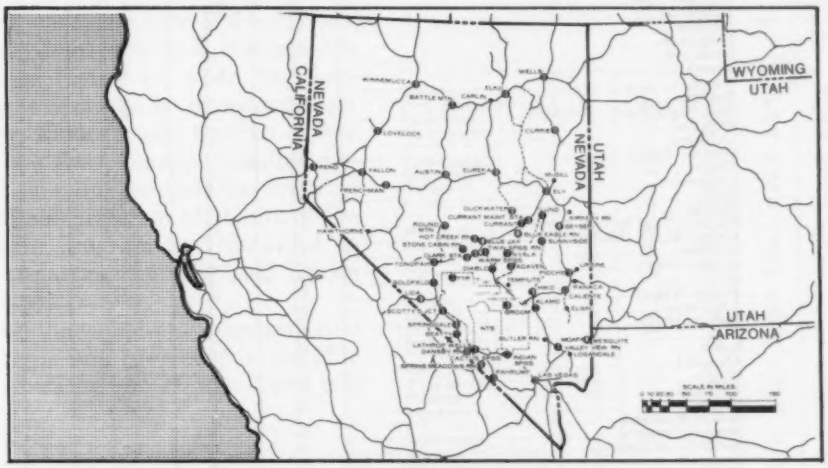

Figure 2. NERC-LV Air Surveillance Network stations in Nevada

Figure 3. NERC-LV Air Surveillance Network stations outside Nevada

Table 1. Summary of gross beta radioactivity concentrations in air, March 1974

	Station location	Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average *
Ariz:	Kingman	13	.6	<0.1	0.3
	Seligman	13	.5	<.1	.3
Calif;	Baker	13	1.0	.2	.4
	Barstow	13	.5	<.1	.2
	Bishop	13	.9	.1	.5
	Death Valley Junction	13	1.4	.1	.5
	Furnace Creek	13	.7	<.1	.4
	Lone Pine	10	.5	<.1	.3
	Needles	12	.6	.3	.4
	Ridgecrest	13	.5	<.1	.3
	Shoshone	13	.6	<.1	.4
Nev:	Alamo	13	1.6	<.1	.4
	Austin	12	.6	.1	.2
	Beatty	13	.6	<.1	.3
	Blue Eagle Ranch (Currant)	13	.7	<.1	.3
	Blue Jay	13	.7	<.1	.3
	Caliente	13	.5	<.1	.3
	Currant Ranch	13	.6	<.1	.3
	Diablo	13	.7	<.1	.4
	Duckwater	13	.6	<.1	.2
	Ely	13	.5	<.1	.3
	Eureka	13	1.3	<.1	.4
	Fallini's Twin Springs Ranch	13	.7	<.1	.3
	Geyser Ranch (Pioche)	6	.6	<.1	.3
	Goldfield	13	.6	<.1	.2
	Groom Lake	13	.6	<.1	.3
	Hiko	13	.6	<.1	.3
	Indian Springs	13	.6	<.1	.3
	Las Vegas	15	1.1	.1	.4
	Lathrop Wells	13	.5	<.1	.3
	Lida	13	.9	<.1	.3
	Lund	13	.8	<.1	.4
	Mesquite	13	.5	<.1	.3
	Nyala	13	.8	<.1	.4
	Pahrump	13	.5	<.1	.3
	Pioche	13	.7	<.1	.3
	Round Mountain	5	.3	.1	.2
	Scotty's Junction	14	.7	.1	.4
	Stone Cabin Ranch	13	.6	<.1	.3
	Sunnyside	13	.6	.1	.3
	Tonopah	13	.5	<.1	.2
	Tonopah Test Range	11	.5	<.1	.3
	Warm Springs	3	.5	<.1	.3
	Warm Springs Ranch	13	.5	<.1	.3
Utah:	Cedar City	13	.6	<.1	.3
	Delta	13	.6	<.1	.3
	Garrison	13	.7	<.1	.3
	Milford	13	.8	.2	.4
	St.1George	13	.5	<.1	.4

* Individual values less than the minimum detectable concentration (MDC) are set equal to the MDC for averaging. A monthly average less than the minimum reportable value of 0.1 pCi/m³ is reported as <0.1.

As shown by table 2, the highest gross beta concentration within the network was 1.6 pCi/m³ at Alamo, Nev.

From gamma spectrometry results, fission products in varying combinations of zirconium-95, ruthenium-103, and cerium-141 were identified on filters collected in Arizona, California, Nevada, and Utah. The highest concentrations of these radionuclides, respectively were 0.41 pCi/m³ (Blue Eagle Ranch, Currant, Nev.), 0.36 pCi/m³ and 0.28 pCi/m³ (Alamo, Nev.). These radionuclides are attributed to annual worldwide fallout. No radionuclides were identified by gamma spectrometry on any charcoal cartridges during March.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA Regional Offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC-LV upon written request.

3. Canadian Air and Precipitation Monitoring Program,[3] March 1974

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Bureau of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Atmospheric Environment Service of the Department of the Environment. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

[3] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for March 1974 are presented in table 3.

Table 3. Canadian gross beta radioactivity in surface air and precipitation, March 1974

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.08	0.06	0.07	28.0	0.5
Coral Harbour	4	.08	.05	.07	315.2	.4
Edmonton	4	.08	.07	.08	15.0	.7
Ft. Churchill	4	.06	.05	.06	53.4	.6
Fredericton	4	.08	.05	.07	22.0	1.8
Goose Bay	4	.05	.03	.04	10.5	.6
Halifax	4	.08	.04	.06	5.7	.6
Inuvik	1	.06	.06	.06	196.9	.1
Montreal	4	.06	.04	.05	23.7	2.2
Moosonee	4	.07	.05	.06	6.1	.2
Ottawa	3	.08	.03	.06	16.9	2.0
Quebec	4	.08	.06	.07	16.5	1.5
Regina	4	.09	.05	.07	38.0	.7
Resolute	4	.06	.05	.06	6.4	.2
St. John's, Nfld	3	.03	.01	.02	25.8	4.2
Saskatoon	4	.08	.05	.07	12.7	.4
Sault Ste. Marie	4	.09	.06	.07	27.7	1.2
Thunder Bay	4	.06	.04	.05	45.8	1.6
Toronto	0				94.7	5.4
Vancouver	4	.04	.03	.04	19.4	3.6
Whitehorse	4	.10	.06	.08	32.3	.3
Windsor	0				46.7	5.4
Winnipeg	4	.08	.05	.07	61.1	.9
Yellowknife	4	.05	.03	.04	22.3	.3
Network summary	83	0.10	0.01	0.06	47.6	1.5

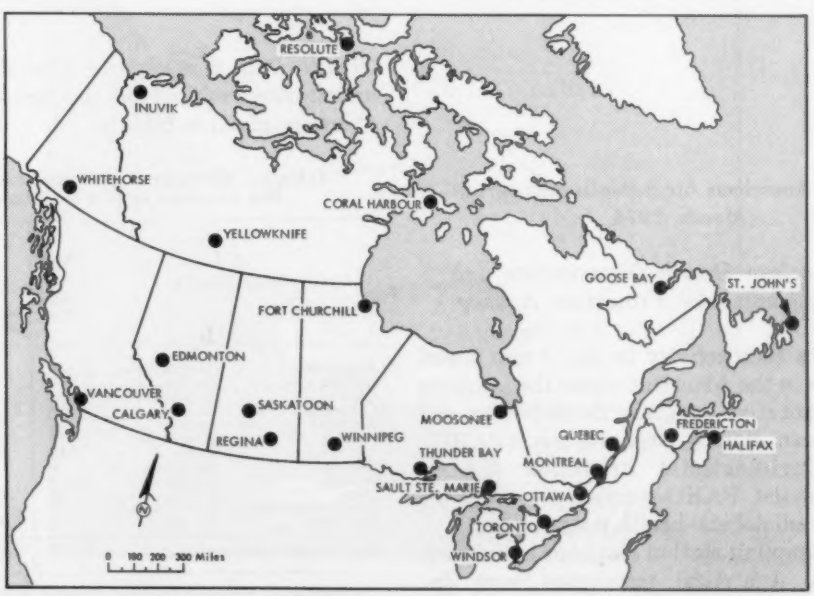

Figure 4. Canadian air and precipitation sampling stations

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Figure 5. Pan American Air Sampling Program stations

4. Pan American Air Sampling Program March 1974

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports.* The March 1974 air monitoring results from the participating countries are given in table 4.

Table 4. Summary of gross beta radioactivity in Pan American surface air, March 1974

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average [a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	0			
Chile:	Santiago	0			
Colombia:	Bogota	19	0.10	0.01	0.02
Ecuador:	Cuenca	16	.02	.00	.01
	Guayaquil	14	.03	.01	.02
	Quito	13	.02	.00	.01
Guyana:	Georgetown	0			
Jamaica:	Kingston	0			
Peru:	Lima	16	.02	.01	.01
Trinidad and Tobago:	Port of Spain	0			
Venezuela:	Caracas	10	.06	.02	.04
Pan American summary		88	0.10	0.00	0.02

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

5. California Air Sampling Program March 1974

Radiologic Health Section
California Department of Health

The Radiologic Health Section of the California Department of Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 6.

One of the objectives of the program is to evaluate the possibility that fixed effluent sources contribute to particulate activity in the air. Consequently, data from continuous air samplers placed in proximity to nuclear facilities are compared with those from similiar equipment in nearby communities and at several "background" stations.[1]

Airborne particles are collected by a continuous sampling of air filtered through a 47

[1] Air samples near nuclear power reactors were obtained under contract number AT(49–1)–3549 between the U.S. Atomic Energy Commission and the California Department of Health.

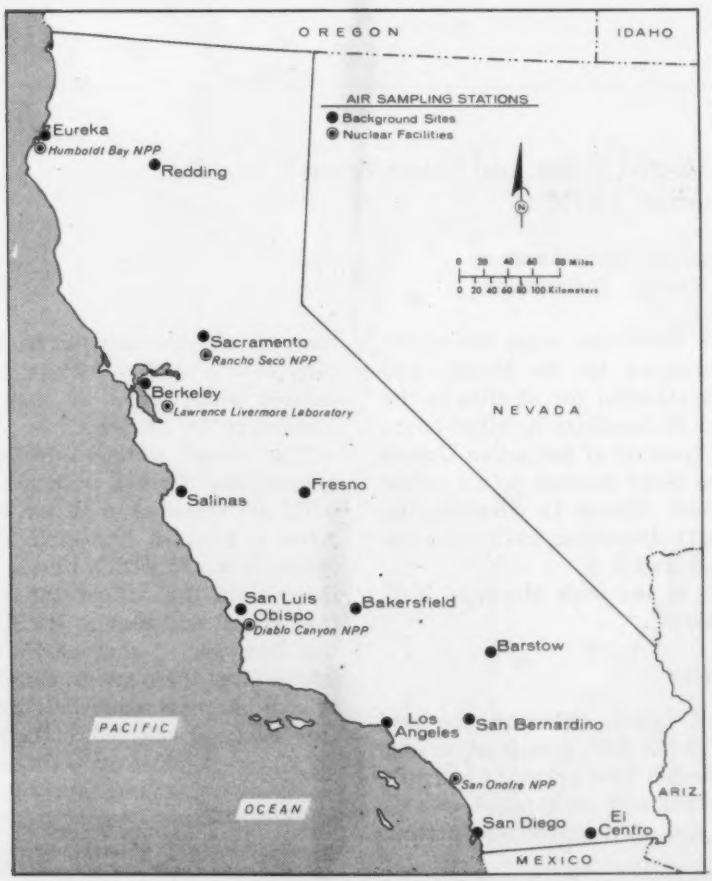

Figure 6. California air sampling program stations

millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Health. The filters are analyzed for gross alpha and beta radioactivity 72 hours after the end of the collection period. The daily samples then are composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. The monthly sample results are presented quarterly. Table 5 presents the gross beta radioactivity in air for March 1974.

Table 5. Gross beta radioactivity in California air, March 1974

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Bakersfield	19	0.74	0.14	0.34
Barstow	30	.80	.02	.41
Berkeley	31	.46	.00	.22
Diablo Canyon Nuclear Power Plant	8	.39	.12	.21
El Centro	20	.70	.25	.44
Eureka	19	.39	.07	.16
Fresno	21	.75	.11	.30
Humboldt Bay Nuclear Power Plant	13	.30	.07	.15
Los Angeles	21	.85	.04	.29
Rancho Seco Nuclear Power Plant	13	.53	.12	.25
Redding	15	.75	.14	.34
Sacramento	21	.46	.01	.19
Salinas	20	.46	.10	.22
San Bernardino	15	.58	.20	.35
San Diego	21	.59	.15	.35
San Luis Obispo	20	.56	.06	.25
San Onofre Nuclear Generating Station	3	.39	.09	.17
Livermore	21	.56	.06	.25
Summary	331	0.85	0.00	0.27

Fallout in the United States and Other Areas [1] January–December 1972

Health and Safety Laboratory
Atomic Energy Commission

Monthly fallout deposition rates for strontium-90 are determined by the Health and Safety Laboratory (HASL) for 35 sites in the United States and 90 locations in other countries. HASL data from all of the active United States stations and other selected points in the Western Hemisphere (figure 1) covering the period from January–December 1972 are summarized in tables 1 and 2.

All the stations of the 80th Meridian Network are represented.

Methods of collection

Two methods of fallout collection are employed by HASL. In the first, precipitation and dry fallout are collected for a period of 1 month in a stainless steel pot with an exposed area of 0.076 m². At the end of the collection period, the contents are transferred, by careful scrubbing with a rubber spatula, to a polyethylene sample bottle which is then shipped to the laboratory for analysis.

The second method involves the use of a polyethylene funnel, with an exposed area of 0.072 m², attached to an ion exchange column. After a 1-month collection, the inside of the funnel is wiped with a tissue, and the tissue is inserted in the end of the column, which is then sealed and sent to HASL for analysis. It has been shown that at the 95-percent confidence level there are no significant differences in the strontium-90 measurements obtained from samples collected by the two methods (*1*).

[1] The data in this article were taken from "Fallout Program Quarterly Summary Report, HASL–278," APP:A1 to A–320.

REFERENCE

(*1*) ONG, L. D. Y. Homogeneity between pot and ion exchanges column strontium-90 measurements. Fallout Program Quarterly Summary Report, HASL–135:256–269. Office of Technical Services, Department of Commerce, Washington, D.C. (April 1, 1963).

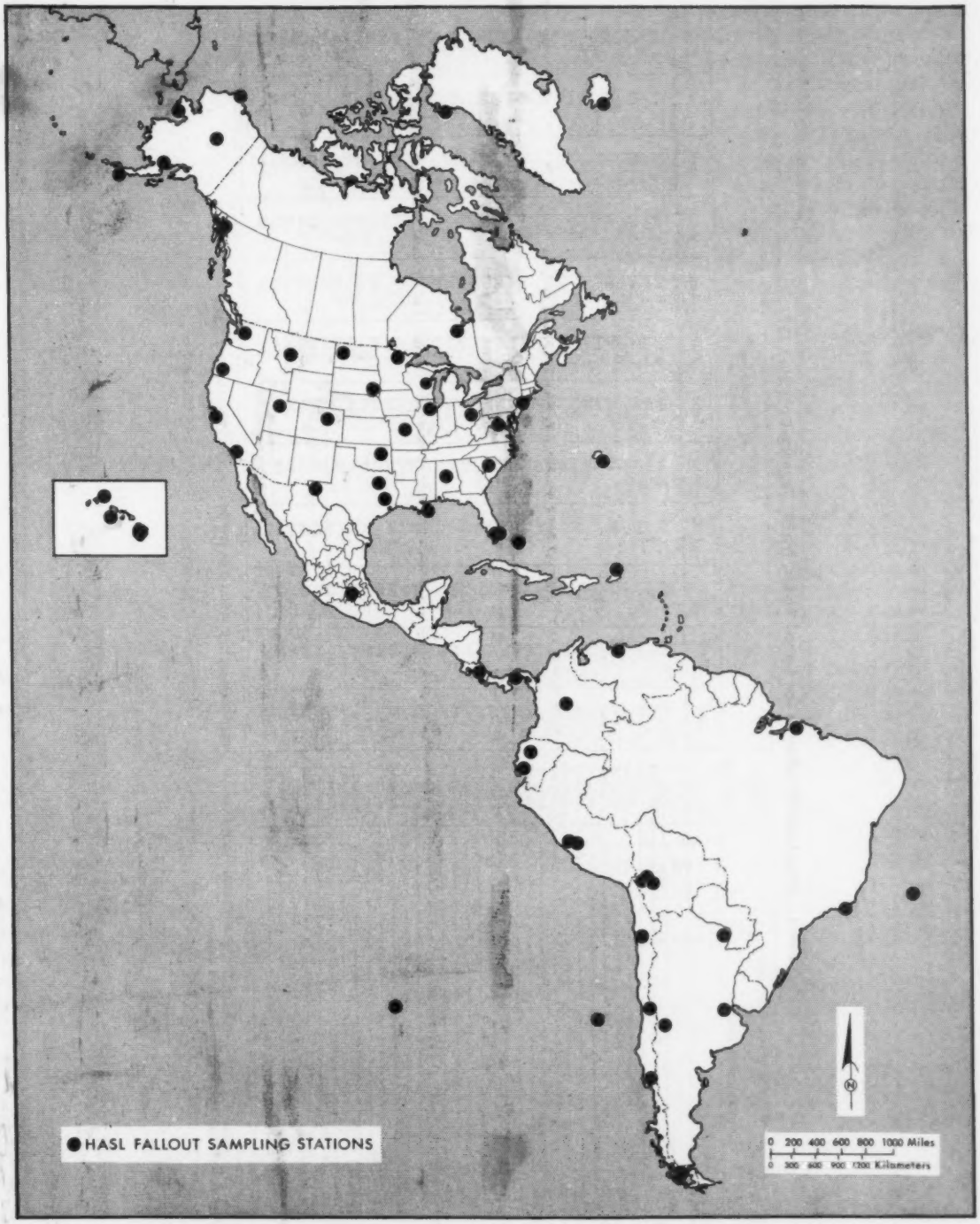

Figure 1. HASL fallout sampling stations in the Western Hemisphere

Table 1. Strontium-90 fallout in the United States, HASL, January-December 1972

Sampling location		Type of collection	Deposition (nCi/m²)											
			Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Ala:	Birmingham	pot	0.06	0.06	0.09	0.04	0.06	0.04	0.05	0.02	0.02	0.03	0.01	0.03
Alaska:	Anchorage	column	.02	[a]	[a]	[a]	.04	.02	.02	.03	[b]	.04	[b]	[b]
	Cold Bay	column	.05	[a]	[a]	.04	.03	.04	.06	.03	.02	.03	.03	.02
	Fairbanks	column	[b]	[b]	[b]	[a]	[b]	[b]	[b]	[b]	[b]	[a]	[a]	[a]
	Juneau	column	[a]	.04	.07	.02	.15	.05	.02	.09	.04	.04	.02	.03
	Nome	column	[a]	[a]	[a]	[a]	[b]	.06	.04	[b]	.03	.01	[a]	[b]
Calif:	W. Los Angeles	pot	[a]	.18	[a]	[a]	.02	.01	[a]	[a]	[a]	[a]	.02	[a]
	San Francisco	column	.02	.04	[a]	.02	[a]	[a]	.02	[a]	[a]	.02	.02	.02
Colo:	Denver	column	[a]	.01	.02	.05	.06	[b]	.20	.01	[a]	[b]	[b]	.03
Fla:	Miami	column	.02	[a]	.02	.02	.18	.06	.05	.03	.02	[a]	.01	.02
Hawaii:	Honolulu	pot	[b]	.14	[b]	.15	.06	.04	[b]	[b]	[b]	[b]	[b]	[b]
	Lihue	column	.05	.08	.04	.15	.02	.04	[a]	.01	.02	.01	[a]	[a]
	Mauna Loa	column	.10	.02	.02	.02	.02	.01	.03	[a]	[a]	[a]	[a]	.04
Ill:	Argonne	pot	.02	.03	.07	.10	.09	.08	.06	.07	.01	[a]	.02	.02
La:	New Orleans	column	.05	.07	.11	.04	.06	.06	.05	.02	.01	.01	.02	.02
Minn:	International Falls	column	.01	[a]	.02	.03	[b]	.06	.09	.04	.02	[a]	[a]	[a]
Mo:	Columbia	column	[a]	.02	.12	.12	.08	.03	.03	.02	.02	.01	.01	.02
Mont:	Helena	column	.04	.01	.02	.02	.06	.06	.05	.03	[a]	.01	[a]	[a]
N.Y:	New York City	pot	.06	.07	.10	.09	.10	.12	.09	.02	.02	[a]	.04	.04
N. Dak:	Williston	column	[a]	[a]	[b]	.06	.13	.10	[b]	.04	.02	[a]	[a]	[a]
Ohio:	Wooster	pot	.02	.02	.02	.04	.04	.03	.02	[a]	[a]	[a]	[a]	[a]
Okla:	Tulsa	pot	[a]	[b]	[c].05	[c].05	.07	.06	[c].01	[c].01	.02	.02	.01	.01
Oreg:	Medford	column	.02	.04	.04	.02	.06	.08	[a]	[b]	.02	[a]	[a]	.05
S.C:	Columbia	column	[a]	.04	.09	.03	.11	.05	.09	.02	[a]	[a]	.02	.05
S. Dak:	Vermillion	pot	[a]	.01	.03	.13	.38	.09	[b]	.04	.04	.02	.02	.02
Tex:	Dallas	column	[a]	.01	.03	.08	.02	.04	.02	[b]	.03	.02	.01	.02
	El Paso	column	.01	[a]	[a]	[a]	.02	[b]	.08	[c].02	[c].01	[a]	[a]	[a]
	Houston	column	.02	[a]	.03	.04	.08	.02	.04	.02	[a]	[a]	[a]	.02
Utah:	Salt Lake City	pot	[b]	.14	.08	.08	.09	.06	.02	.02	.01	.03	[a]	[a]
Va:	Sterling	column	.04	.04	.03	.09	.05	.08	.06	.03	[a]	.02	.02	.02
Wash:	Seattle	pot	.05	.06	.11	.09	.04	.26	.10	.12	.08	.04	.02	.05
	Forks	column	.12	.24	.28	.06	.03	.05	.09	.02	.03	[a]	.04	.09
Wisc:	Green Bay	column	[a]	[a]	[c].04	[c].04	.04	.04	.04	.07	.03	[a]	[a]	.04

[a] Zero or trace.
[b] Data not available.
[c] Proportioned from originally consolidated data.

Table 2. Strontium-90 fallout in North and South America, HASL, January-December 1972

Sampling location		Type of collection	Deposition (nCi/m²)											
			Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Argentina:	Buenos Aires	column	0.03	0.13	0.09	0.03	0.02	0.05	0.04	0.06	0.07	0.03	0.06	0.08
	Formosa	column	.04	.05	.05	.02	.02	.04	.02	.03	.02	.03	.04	.02
	Malargue	column	.02	.06	.01	.02	.02	.02	.03	(a)	.03	.02	.07	(b)
Bahamas:	Bimini	column	(b)	(b)	(b)	.02	.03	.02	(a)	.05	(a)	(a)	(a)	(b)
Bermuda:	Kindley AFB	column	.02	.10	.11	.02	.05	.08	.02	.03	(a)	(a)	(a)	.01
Bolivia:	Chacaltaya	column	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
	La Paz (city)	column	.03	.01	(a)	(a)	(a)	(a)	(a)	.01	.01	(a)	(a)	(a)
	La Paz (Ovejuyo)	column	.02	(a)	(a)	(a)	(a)	(a)	(a)	(a)	.01	.02	(a)	(a)
Brazil:	Belem	column	.03	.04	.04	(a)	(a)	(a)	.03	(a)	(a)	.02	(a)	(a)
	Rio de Janeiro	column	.06	.06	.04	.05	.04	(b)	(b)	(b)	(b)	(b)	(b)	(b)
	Trinidade Island	column	(b)	(a)	.03	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Canada:	Moosonee	column	.01	(a)	(a)	(a)	.03	.04	.09	.04	.02	.02	(a)	(a)
Canal Zone:	Balboa	column	(b)	(a)	(b)	.03	.02	.02	(a)	(a)	(a)	(b)	.01	.01
Chile:	Antofagasta	column	(b)	(b)	(a)	(a)	(a)	(a)	(a)	(b)	(b)	(b)	(b)	(b)
	Conception	column	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	.02	(a)
	Easter Island	column	.05	.04	.09	.02	.04	.06	.06	.03	.02	(a)	.02	.02
	Puerto Montt	column	.08	(b)	.13	.03	(b)	.07	.09	.10	(b)	(b)	(b)	.04
	Punta Arenas	column	(b)	.02	(a)	(a)	(b)	.01	.02	.02	.02	.02	(a)	(a)
	Santiago	pot	(a)	(a)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
	Santiago	column	.01	.01	(a)	(a)	(b)	.12	.09	.09	.10	.04	(a)	(a)
Colombia:	Bogota	pot	(a)	(a)	(a)	(a)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Costa Rica:	Turrialba	column	.01	.05	.02	.04	(a)	.02	.02	(a)	(a)	(a)	(a)	.01
Equador:	Guayaquil	column	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Greenland:	Thule	column	(a)	(a)	(a)	(a)	(a)	.02	.03	(a)	(a)	(a)	(a)	(a)
Iceland:	Keflavik	column	.05	(b)	.03	.04	.07	.06	.08	.05	.02	.02	(a)	(b)
Mexico:	Mexico City	column	(a)	(b)	(b)	.04	.04	.02	(a)	(a)	.02	(a)	(b)	(b)
Peru:	Lima	column	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	.02	(a)	(a)	(a)
Puerto Rico:	San Juan	column	.02	.03	.03	.02	.01	.03	(b)	.03	.02	(a)	(a)	.02
Venezuela:	Caracas (site 1)	column	(b)	(b)	.03	.02	(a)	(b)	(a)	(b)	.02	(a)	(a)	(a)

[a] Zero or trace.
[b] Data not available.
[c] Proportioned from originally consolidated data.

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors annual reports on the levels of environmental contaminants including radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required. From the complete environmental monitoring reports published in a compendium report entitled "Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar year 1972," WASH 1259, those portions dealing with radioactivity are summarized for *Radiation Data and Reports*. Statements interpreting the radioactivity data are those of the USAEC contractors. The units for the data as reported in WASH-1259 have been converted from the format required by the AEC to that used by *Radiation Data and Reports*. The Environmental Protection Agency has not independently or critically reviewed the data or the conclusions derived therefrom.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for Argonne National Laboratory, Bettis Atomic Power Laboratory, and the Paducah Plant.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Argonne National Laboratory[2] January–December 1972

University of Chicago
Lemont, Ill.

Argonne National Laboratory (Illinois site) is located on a 3740-acre site in DuPage County, 27 miles southwest of downtown Chicago and 24 miles west of Lake Michigan. It lies south of Interstate Highway 55 and west of Illinois Highway 83. The terrain is rolling, partially-wooded, former prairie and farmland. The grounds contain a number of ponds and small streams, the principal one being Sawmill Creek, which runs through the site in a southerly direction and enters the Des Plaines River about 1.3 miles southeast of the center of the site. The land is drained primarily by Sawmill Creek, although the extreme southern portion drains directly into the Des Plaines River. This river flows southwest until it joins the Kankakee River about 30 miles southwest of the laboratory to form the Illinois River.

Argonne is a multidisciplinary research and development laboratory with two principal objectives: it carries out a broad program of basic research activities, and it serves as an

[2] Summarized from "Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites—Argonne National Laboratory Annual Report for 1972."

important center for the design and development of nuclear reactors. Most of the basic research is concerned with the application of radiation as a tool in the physical and life sciences. The reactor effort is devoted largely to development of the liquid-metal-cooled fast-breeder power reactor. Almost all of the work at the laboratory is of an unclassified nature and deals with peacetime applications of nuclear energy.

The principal nuclear facilities at the laboratory are a 5 MW heavy-water cooled and moderated general-purpose research reactor (CP-5) fueled with fully-enriched uranium; a 200 kW light-water cooled and moderated biological research reactor (JANUS) fueled with fully-enriched uranium; a 12.5 GeV proton accelerator, the Zero Gradient Synchrotron (ZGS); two critical assemblies, or zero power reactors (ZPR-6 and -9), that are fueled at various times with plutonium, uranium, or a combination of the two; a 60-inch cyclotron; several Van de Graaff accelerators; a fuel fabrication facility designed for plutonium usage; and several hot cells and laboratories designed for work with irradiated fuel elements and with multicurie quantities of the actinide elements.

The radioactivity of the environment was

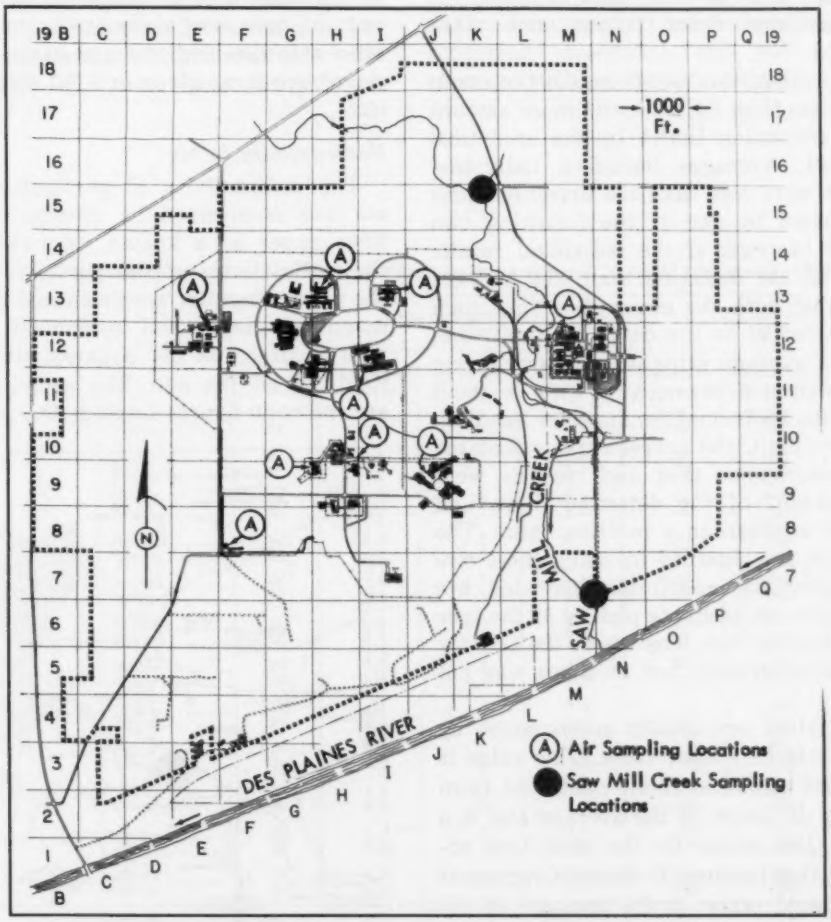

Figure 1. Onsite sampling locations at Argonne National Laboratory

determined by measuring the concentrations of radioactive nuclides in naturally-occurring materials and by measuring the external penetrating radiation dose. Sample collections and measurements were made both on and off the site for comparison purposes. Since radioactivity is usually spread by air and water, the sample collection program has concentrated on these media. In addition, soil, plants, milk, precipitation, animals, and material from the beds of lakes and streams were also collected and analyzed. The results included in this report are those that are pertinent to the evaluation of Argonne's contribution to the environmental radioactivity and to the differentiation of Argonne activity from fallout and other sources.

When a nuclide was not detected, the result is given as less than ($<$) the minimum amount detectable (detection limit) by the analytical method used. Averages including individual results that were less than the detection limit were calculated by one of the following two methods. If the bulk of the individual results was less than the detection limit, the average was calculated with the assumption that such results were equal to the detection limit, and the resulting average value is expressed as less than the computed average. If only a small fraction of the individual results were less than the detection limit, the average was calculated with the assumption that such results were actually one-half of the detection limit, and the average is given as a positive value. The averages that are obtained by using these two methods under the conditions indicated are believed to give an adequate picture of the true average activity at locations where the activity not only varied greatly, but at times was not detectable.

Average values are usually accompanied by a plus-or-minus ($\pm$) limit value. This value is the 95-percent confidence limit calculated from the standard deviation of the average and is a measure of the range in the activities encountered at that location. It does not represent the conventional error in the average of repeated measurements on the same or identical samples. Since many of the variations that occur in environmental radioactivity are not random but occur for specific reasons (e.g., nuclear testing), samples collected from the same location at different times are not replicates. The more random the variation in activity at a particular location, the closer the confidence limits will represent the actual distribution of values at that location. The averages and confidence limits should be interpreted with this in mind. When a $\pm$ figure accompanies an individual result in this report, it represents the statistical counting error at the 95-percent confidence level.

Where environmental quality standards have been established, the measured concentration or radiation dose is compared with the standard as a means of assessing its hazard. Unless otherwise specified, the standards used in this report are those given in AEC Manual Chapter 0524.

Radioactivity in air

The radioactivity of particulate matter in air was determined by drawing air through filter paper at a known rate and measuring the radioactivity of the particles collected by the paper. Samples were collected continuously, except for occasional equipment failures, at nine locations on the Argonne site and at six locations off the site. The sampling locations are shown in figures 1 and 2. At one location on

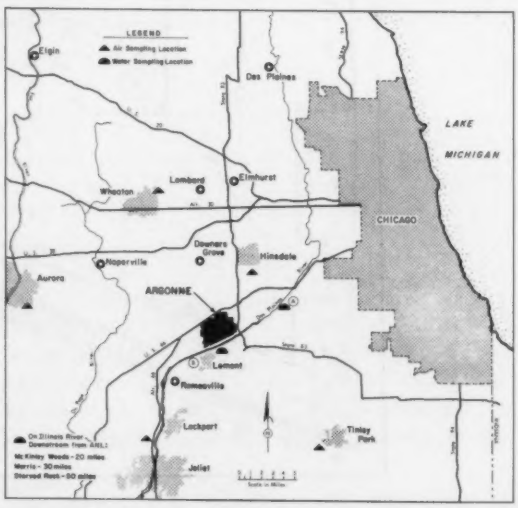

Figure 2. Location of Argonne National Laboratory (including some offsite sampling locations)

the site, the filter paper was changed daily; at all other locations, the filter papers were changed at weekly intervals. The daily samples record short-term changes in radioactivity, while the weekly samples are used to compare onsite and offsite activities. Higher activities on the site are indicative of radioactivity released by Argonne if the differences are greater than the error in sampling and counting. This error is between 5 and 20 percent for most results, but approaches 100 percent at the detection limit.

The total alpha and beta radioactivities in the weekly samples are given in table 1. The alpha and beta radioactivities were measured in low-background gas-flow proportional counters, and the counting efficiencies used to convert counting rates to disintegration rates were those measured for radon decay products on filter paper. The average concentrations of a number of gamma-ray emitters, as determined by gamma-ray spectrometry performed on composite weekly samples, are given in table 2. The gamma-ray measurements were made with a spectrometer that used a shielded 35 cm^3 lithium-drifted germanium diode as the detector. The detector was calibrated for each gamma-emitting radionuclide given in table 2.

The activities were very similar on and off the site and no significant differences between the locations were found. This indicates that Argonne did not add detectably to the average airborne particulate activity of the environment during the year, and that the activities originated in widespread sources (such as fallout from nuclear test detonations and naturally-occurring materials) and not in localized sources (such as the laboratory).

Table 1. Alpha and beta radioactivity in air-filter samples,[a] Argonne National Laboratory, 1972

Month	Location	Number of samples	Alpha radioactivity (fCi/m^3)			Beta radioactivity (pCi/m^3)		
			Maximum	Minimum	Average	Maximum	Minimum	Average
January	Onsite	40	3.4	1.0	2.3	0.26	0.042	0.11
	Offsite	22	6.1	.8	2.6	.22	.023	.13
February	Onsite	32	4.0	1.3	2.4	.13	.062	.087
	Offsite	21	12.5	1.3	3.4	.23	.041	.095
March	Onsite	34	3.2	.9	2.2	.10	.046	.075
	Offsite	26	8.2	1.3	2.8	.11	.035	.078
April	Onsite	34	4.5	1.3	2.7	.32	.045	.094
	Offsite	21	4.8	1.5	2.6	.37	.058	.094
May	Onsite	35	7.0	2.1	3.5	.67	.086	.21
	Offsite	23	6.1	1.7	3.3	.60	.065	.23
June	Onsite	34	8.0	1.0	3.1	.44	.11	.21
	Offsite	22	5.1	1.2	2.6	.30	.11	.18
July	Onsite	37	6.8	1.1	3.2	.30	.060	.14
	Offsite	23	3.8	1.1	2.5	.27	.069	.14
August	Onsite	32	4.1	.6	2.1	.12	.042	.072
	Offsite	25	3.1	.9	1.9	.16	.048	.073
September	Onsite	37	3.8	.7	1.9	.089	.026	.050
	Offsite	24	3.0	.8	1.8	.082	.022	.048
October	Onsite	37	4.1	.7	1.9	.074	.017	.036
	Offsite	26	4.4	.9	2.1	.066	.023	.036
November	Onsite	35	7.3	.3	1.6	.072	.014	.032
	Offsite	22	5.6	.9	1.8	.054	.017	.028
December	Onsite	34	4.3	.3	1.9	.28	.023	.046
	Offsite	24	4.4	.7	2.1	.065	.023	.040
Annual summary	Onsite	421	8.0	0.3	2.4±0.3	0.67	0.014	0.097±0.035
	Offsite	279	12.5	0.7	2.5±0.3	0.60	0.017	0.098±0.036

[a] These results were obtained by measuring the samples 4 days after they were collected in order to avoid counting the natural radioactivity due to radon and thoron decay products. This activity is normally present in the air and disappears within 4 days by radioactive decay.

Table 2. Gamma-ray radioactivity in air-filter samples, Argonne National Laboratory, 1972

Radionuclide	Location	Concentration (fCi/m³)												
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual average
Antimony-125	Onsite	1	<1	1	1	2	2	1	<1	<1	<1	<1	<1	1± 1
	Offsite	1	<1	1	1	2	2	1	<1	<1	<1	<1	<1	1± 1
Barium-lanthanum-140	Onsite	6	4	1	2	4	2	1	<1	<1	<1	<1	<1	2± 4
	Offsite	6	3	1	2	4	2	1	<1	<1	<1	<1	<1	2± 4
Beryllium-7	Onsite	70	81	116	103	150	140	105	85	95	91	67	85	99±54
	Offsite	70	74	108	105	158	120	97	80	88	87	66	81	95±52
Cerium-141	Onsite	2	2	1	2	10	10	6	2	1	<1	<1	<1	3± 7
	Offsite	3	2	1	1	10	9	6	2	1	<1	<1	<1	3± 6
Cerium-144	Onsite	10	10	13	11	23	23	14	7	6	3	2	2	10±13
	Offsite	9	9	14	12	22	20	14	6	5	3	2	2	10±12
Cesium-137	Onsite	1	2	2	2	3	3	2	1	1	1	<1	<1	2± 2
	Offsite	1	1	2	2	3	3	2	1	1	1	<1	<1	2± 2
Cobalt-60	Onsite	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Offsite	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iodine-131	Onsite	50	10	<10	10	10	<10	<10	<10	<10	<10	<10	<10	10±35
	Offsite	60	10	10	10	10	<10	<10	<10	<10	<10	<10	<10	11±32
Manganese-54	Onsite	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Offsite	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ruthenium-103	Onsite	4	4	1	2	16	20	15	5	3	1	<1	<1	6±12
	Offsite	5	4	2	2	15	18	14	4	3	1	<1	<1	6±11
Ruthenium-rhodium-106	Onsite	3	5	6	5	11	12	8	3	2	<1	<1	<1	5± 7
	Offsite	3	3	6	4	9	10	7	3	2	<1	<1	<1	4± 6
Zirconium-niobium-95	Onsite	6	6	5	6	45	55	35	15	8	3	1	2	16±35
	Offsite	5	4	4	5	45	46	32	11	6	4	2	2	14±31

The alpha radioactivities averaged 25 percent lower than 1971, but were still in their normal range. The alpha emitters in the air samples are principally naturally-occurring radionuclides. About two-thirds of the gamma activity and a smaller fraction of the beta radioactivity was due to beryllium-7, produced in the stratosphere by cosmic-ray interactions. Most of the remaining beta and gamma activity was due to fission and neutron activation products from nuclear test detonations. Except for the short-lived fission products, the activities, including the naturally-occurring beryllium-7, increased in concentration from January to May, then generally decreased during the remainder of the year. This variation can be attributed to the usual "spring maximum" in the stratospheric fallout rate. The fact that the concentrations of the longer-lived fission products varied in approximately the same manner as beryllium-7 (except that they decreased at a greater rate during the latter part of the year through radioactive decay and fallout, since, unlike beryllium-7, they are not produced continuously) is evidence that the bulk of the fission products was also derived from the stratosphere.

The detection of short-lived fission products (iodine-131 and barium-140) at all sampling locations during the last quarter of 1971 and the first half of 1972, indicates the presence of fallout from a series of tests conducted during this period. The increase in 40-day half-life ruthenium-103, 65-day half-life zirconium-95, and 32-day half-life cerium-141 in the spring implies a recent injection of fission products into the atmosphere at high altitudes. The variations with time in the concentrations of the short-lived fission products correlate with the dates of announced nuclear tests.

The average beta radioactivity for the year, 0.1 pCi/m^3, was about 3 times lower than in 1971. This was principally due to substantial decreases in the concentration of intermediate half-life fission products: cerium-144, ruthenium-106, and zirconium-95. The decreases are greater than can be accounted for on the basis of radioactive decay. Since the levels of beryllium-7 have been constant over the past years, these lower concentrations indicate a depletion of fission products in the stratospheric reservoir. The results obtained for the air filter samples are further summarized in table 3 in order to compare the average concentrations with the concentration guides. Regardless of source, all concentrations were well below the AEC standard.

Table 3. Average particulate radioactivity in air-filter samples, ANL, 1972

Radionuclide	Detection limit [a] (pCi/m^3)	AEC standard [a] (pCi/m^3)	Concentration (pCi/m^3)	Percent of AEC standard
Antimony-125	0.001	900	0.001	0.0001
Barium-lanthanum-140	.001	1 000	.002	.0002
Beryllium-7	.001	40 000	.099	[b] .0002
Cerium-141	.001	5 000	.003	.00006
Cerium-144	.001	200	.010	.005
Cesium-137	.001	500	.002	.0004
Cobalt-60	.001	300	<.001	<.0003
Iodine-131	.01	100	.010	.010
Manganese-54	.001	1 000	<.001	<.0001
Ruthenium-103	.001	3 000	.006	.0002
Ruthenium-rhodium-106	.001	200	.005	.003
Zirconium-niobium-95	.001	1 000	.016	.002
Alpha	.0002	10	.0024	[b] .024
Beta	.0005	10	.097	.97

[a] The AEC standards are those given in US AEC Manual Chapter 0524 for uncontrolled areas.
[b] This radioactivity is due to naturally occurring radionuclides.

Air was sampled continuously for radioiodine with activated charcoal in the 200 and 300 Areas because of the possibility of iodine releases in these areas. Very small amounts of iodine-131, up to 0.15 pCi/m^3 (0.15 percent of the uncontrolled AEC standard), were detected in January and February and were probably produced in nuclear tests conducted late in 1971, along with the other short-lived fission products found in the air filter samples. No iodine radioactivity was detected at any other time during the year at either location.

Air sampling for plutonium was begun in March in the northeast area of the site (12N, figure 1) and in October at 10H in the 300 Area close to the center of plutonium usage on the site. Offsite sampling for plutonium will be initiated early in 1973. Monthly samples were collected on a polystyrene filter medium at flow rates of 35 or 85 m^3/h, depending on the sampler. The total air volume filtered for each sample was about 30 000 and 65 000 m^3, respectively. Samples were ignited at 600°C to remove organic matter and prepared for plutonium analysis by vigorous treatment with hot hydrochloric, hydrofluoric, and nitric acids.

This treatment has been found in our laboratory to solubilize plutonium that has been ignited at 1000°C. The plutonium was separated from nitric acid solution on an anion-exchange column, electrodeposited, and its composition determined by alpha spectrometry. Alpha spectrometry cannot distinguish between plutonium-239 and -240, and although in the following discussion, and in the tables, only plutonium-239 is mentioned, it should be understood that the alpha radioactivity due to the less abundant plutonium-240 isotope is also included. The chemical recovery was determined by adding a known amount of plutonium-236 tracer to the sample before ignition. The chemical separation procedure also yields a separated thorium fraction, and this fraction was also electrodeposited and measured in an alpha spectrometer beginning with the June samples. To obtain the thorium recovery for these samples, thorium-234 was added prior to ignition. An aliquot of the sample solution was also analyzed for uranium by a standard type of fluorophotometric procedure. The uranium concentrations are obtained in mass units by this technique. Since the uranium is believed to have the normal isotopic composition, the results were converted to activity units for comparison purposes by use of the specific activity of natural uranium, 675 nCi/g. The results are given in table 4.

The plutonium concentrations show the same general monthly variation discussed earlier for gamma-ray emitters (table 2). The concentrations are also similar to those reported by other investigators (*1–2*) for samples collected at similar latitudes, but away from nuclear installations.[3] The monthly variations and the similarities between the samples collected by other laboratories indicate that the plutonium in the samples on the Argonne site is primarily from fallout. The October 10H concentration (41 aCi/m³), although within the yearly range, does not follow the monthly trend. The reason for this discrepancy is not clear, although at least two possibilities exist. The concentrations of the thorium isotopes are similar in most samples, about 20 aCi/m³ for thorium-232 and thorium-228 and about 30 aCi/m³ for thorium-230. The October 10H sample was in this range, while the October 12N sample, for some reason, filtered relatively few particles and therefore the plutonium concentrations in the air were actually about four times greater than found at 12N. This implies, incidentally, that the

[3] E. P. Hardy, Jr., USAEC Health and Safety Laboratory, personal communication (February 20, 1973).

Table 4. Plutonium, thorium, and uranium concentrations in air-filter samples, ANL, 1972

Month	Location	Concentrations (aCi/m³)					
		Plutonium-239	Plutonium-238	Thorium-232 [a]	Thorium-228	Thorium-230	Uranium [a]
March	12N	31 ±3	3.3±1.0				
April	12N	33 ±3	4.2±1.5				316±41
May	12N	41 ±3					146± 9
June	12N	45 ±3	2.9± .9	20 ±1	26 ±1	33± 2	90± 8
July	12N	32 ±3	1.5± .8	75 ±2	75 ±2	113± 3	77± 4
August	12N	28 ±2	1.2± .8	23 ±2	28 ±3	36± 3	121±28
September	12N	17 ±2	1.5±1.1	20 ±2	16 ±3	27± 3	63± 9
October	12N	7.6±3.0	<1	4.8±1.8	4.1±1.5	12± 3	40± 8
	10H	41 ±3	2.5±1.2	24 ±3	20 ±3	42± 2	79±14
November	12N	6.6±3.3		15 ±2	20 ±3	29± 3	89±13
	10H	7.8±2.0		20 ±2	28 ±2	36± 2	85±18
December	12N	11.2±1.4	2.4± .9	18 ±2	23 ±3	40± 3	125±30
	10H	9.1± .8	1.2± .4	26 ±2	21 ±2	48± 2	83±29
Monthly average		27 ±9	2.2± .7	27 ±15	29 ±15	45±23	118±52
Percent AEC standard		.003	.0002	(.003)	(.015)	(.015)	(.003)
AEC standard		1×10^4	1×10^5	1×10^4	2×10^4	3×10^4	4×10^{b}
Detection limit		1	1	1	1	1	20

[a] The concentrations in units of pg/m³ can be obtained by multiplying the value in aCi/m³ by 1.48 for uranium and by 9 for thorium-232. The amounts of the other two thorium isotopes in mass units are negligible in comparison to thorium-232. The average thorium and uranium concentrations are 240 pg/m³ and 170 pg/m³, respectively.

[b] Parentheses indicate that the radioactivity is due to the naturally-occurring radionuclide.

plutonium fallout rate was unusually high during October. A second possibility is that the plutonium-239 fallout was actually closer to 8 aCi/m³ than 40 aCi/m³, and that the additional plutonium, about 30 aCi/m³ was due to plutonium from Argonne. An explosion involving plutonium occurred in Building 205 (location 12H), north of the 12N sampler on October 17, 1972, when the wind was from the north-northwest (330°), but was relatively calm (about 3–4 mph at the 19 foot level and about 6 mph at the 150 foot level). However, there is no unequivocal corroborating evidence that any plutonium escaped from Building 205 since, as will be seen, soil samples collected downwind from the building did not confirm a release. From whatever sources, the total plutonium-239 concentration, 41 aCi/m³, was very low compared to the exposure standards, 0.004 percent of the AEC standard for uncontrolled areas and 0.0001 percent of the AEC standards for controlled areas.

The thorium and uranium concentrations given in table 4 are considered to be of natural origin. There is no indication that any of these elements in the air samples originated at Argonne. The percent of AEC standards for these activities is included for purposes of completeness.

Air sampling for argon-41, a beta emitter with a 1.8 hour half-life that is produced in an operating reactor by neutron irradiation of the stable argon in air, was conducted near the CP-5 reactor (Building 330, 9H, figure 1). Samples were collected by filling out an evacuated "Marinelli type" container once a day from 2 to 5 times during each week of reactor operation and the argon-41 measured by gamma-ray spectrometry. Each sampling consisted of two "grab" samples, one taken 45 meters east of the reactor and one downwind from the reactor at a point favorable for detection of argon-41. The results are given in table 5. Because of the timing and location of the sample collection, the actual average concentration in the vicinity of the reactor was less than the values in the table. The average and maximum concentrations of 0.12 and 1.2 μCi/m³ are, respectively, about 3 and 30 times the AEC standard for uncontrolled areas and 0.060 and 0.6 times the AEC standard for controlled areas. In this case, comparison with the AEC standard for controlled areas is more appropriate since the sampling is conducted on the site and the argon-41 originated in the reactor. At the site security fence, the closest uncontrolled approach to the laboratory, the concentrations were less than the detection limit, 20 nCi/m³. Based on penetrating radiation measurements, the concentration at the fence averaged less than 800 pCi/m³, the concentration that would give a dose of 10 mrem/year.

Tritium (tritiated) water vapor in the air was monitored on and off the site because substantial amounts are in use at the laboratory. Water vapor was removed from the air by absorption on silica gel and the tritium measured by counting the water in a liquid scintilla-

Table 5. Argon-41 concentrations in air, 300 Area, ANL, 1972

Month	Number of samples	Concentration (nCi/m³)			Percent of AEC standard [a]		
		Maximum	Minimum	Average	Maximum	Minimum	Average
January	16	335	<20	56	17	<1	3
February	18	1 160	<20	100	58	<1	5
March	12	1 160	<20	180	58	<1	9
April	16	1 000	<20	180	50	<1	9
May	14	500	<20	125	25	<1	6
June	16	420	<20	82	21	<1	4
July	16	950	<20	140	48	<1	7
August	8	220	<20	81	11	<1	4
September	16	1 160	<20	120	58	<1	6
October	12	695	<20	150	35	<1	8
November	16	430	<20	73	22	<1	4
December	16	815	<20	160	41	<1	8
Annual summary	176	1 160	<20	121 ± 25	58	<1	6

[a] This is the AEC standard for controlled areas.

Table 6. Tritium concentrations in air, 300 Area, ANL, 1972

Month	Number of samples	Concentration (pCi/m³)			Percent of AEC standard *		
		Maximum	Minimum	Average	Maximum	Minimum	Average
January	8	880	1.5	210	0.44	0.00075	0.10
February	8	587	11.6	146	.29	.0058	.073
March	16	781	.94	117	.39	.00047	.058
April	18	274	4.3	99	.14	.0022	.050
May	18	1 121	3.4	145	.56	.0017	.072
June	14	718	6.1	194	.36	.0030	.097
July	9	260	18.5	126	.13	.0092	.063
August	9	367	86.0	166	.18	.043	.083
September	9	178	24.3	78	.089	.012	.039
October	9	497	8.7	117	.25	.0043	.058
November	7	389	11.4	114	.19	.0057	.057
December	9	357	30.7	115	.18	.015	.076
Annual summary	134	1 121	0.94	139 ± 22	0.56	0.00047	0.070

* This is the AEC standard for uncontrolled areas.

ion counter. Tritium is produced continuously in an operating reactor by several methods. In CP-5, the largest source is by neutron irradiation of the heavy water used for cooling and neutron moderating. Air was sampled continuously for tritiated water vapor at a permanent station 45 meters east of the CP-5 reactor, and during the first half of the year, 180 meters from the reactor in various directions. The results, given in table 6, were all positive, although the concentrations were well below the AEC standard. In the uncontrolled area, AEC standards are shown in table 6 to allow easy comparison with the offsite concentrations discussed below. As in the case of argon-41 near the reactor, application of the AEC standard for controlled areas is appropriate. The percent of AEC standard for controlled areas is 25 times less than the values in table 6. As will be seen, normal or background tritium concentrations in air during 1972 ranged from 0.2 to 8.6 pCi/m³ and averaged about 2.4 pCi/m³. Near CP-5, the average was 140 pCi/m³ and the difference was due to tritium that left the reactor building. The average concentration near the reactor was almost 3 times lower than in 1971 because a leak that developed in the heat exchanger last year was repaired.

As an extension of a study begun in 1971, air was also sampled for tritiated water vapor at two site security fence locations, 590 meters directly west (10E) and 480 meters directly south (8H) of the reactor. These two locations are the closest uncontrolled approaches to CP-5. Samples were also collected once a month at an onsite location in the East Area, 1800 meters northeast of the CP-5 reactor and offsite at a location approximately 9.6 km northwest of the laboratory. The results are given in table 7. The fence line results show good correlation with wind direction and indicate that dilution to background levels occurs within 450–550 meters of the reactor in directions other than that from which the wind is blowing. The average and maximum concentrations were equivalent to 0.008 and 0.05 percent of the AEC standard, respectively. The average fence line concentration corresponds to a dose of 0.038 mrem/year, about 85 percent from Argonne operations and the remainder from weapons testing.

The higher concentrations in the east area compared to offsite concentrations may also be attributed to CP-5. Measurements from previous years show that when the wind was from the southwest and the tritium concentration near the reactor was sufficiently high, measurable increases above the normal background level can be observed.

The offsite concentrations, which may be considered as normal for this area, decreased by a factor of two over the 1971 values. Most of this tritium was produced in nuclear test detonations, and a decrease is expected, since few atmospheric tests were conducted in 1971 and 1972. Much of the test-produced tritium has been transported from the atmosphere to the hydrosphere.

Table 7. Tritium concentrations in air, Argonne National Laboratory, 1972

Month	Location	Number of samples	Concentration (pCi/m³)			Percent of AEC standard *		
			Maximum	Minimum	Average	Maximum	Minimum	Average
January	East area	1	2.6			0.0013		
	Offsite	1	.68			.00034		
February	East area	1	11.0			.0055		
	Offsite	1	.87			.00043		
March	East area	1	.43			.00022		
	Offsite	1	.18			.00009		
April	East area	1	2.2			.0011		
	Offsite	1	1.6			.00080		
May	East area	1	2.7			.0013		
	Offsite	1	2.9			.0014		
June	South fence (8H)	2	56.7	13.7	35.2	.028	0.0068	0.018
	East area	1	6.1			.0030		
	Offsite	1	8.6			.0043		
July	South fence (8H)	9	13.2	2.5	8.4	.0066	.0012	0.0042
	East area	1	14.7			.0074		
	Offsite	1	6.5			.0032		
August	West fence (10E)	9	8.1	2.8	5.8	.0040	.0014	.0029
	East area	1	3.9			.0020		
	Offsite	1	2.5			.0013		
September	South fence (8H)	9	55.6	.77	13.5	.028	.00038	.0068
	East area	1	5.4			.0027		
	Offsite	1	2.5			.0013		
October	South fence (8H)	9	96.0	.33	26.7	.048	.00016	.013
	East area	1	3.5			.0017		
	Offsite	1	.89			.00044		
November	South fence (8H)	7	59.0	.29	16.0	.029	.00014	.0080
	East area	1	2.3			.0011		
	Offsite	1	.84			.00041		
December	West fence (10E)	9	3.7	.82	1.8	.0019	.00041	.00088
	East area	1	2.4			.0012		
	Offsite	1	.38			.00019		
Annual summary	Fence line	54	96.0	0.29	15.3 ±9.0	0.048	0.00014	0.0076
	East area	12	14.7	0.43	4.8 ±2.4	0.0074	0.00022	0.0024
	Offsite	12	8.6	0.18	2.4 ±1.5	0.0043	0.00009	0.0012

* This is the AEC standard for uncontrolled areas.

Radioactivity in surface water

Total (nonvolatile) alpha and beta radioactivities were determined by counting the residue remaining after evaporation of the water, and applying counting efficiency corrections determined for uranium-233 (for alpha radioactivity) and thallium-204 (for beta radioactivity), respectively, to obtain disintegration rates. Tritium was determined by liquid scintillation counting of a separate sample, and this activity does not appear in the total beta radioactivity. Uranium was determined fluorophotometrically, and the results calculated in terms of activity, assuming the isotopic composition of natural uranium. Analyses for other radionuclides were performed by specific radiochemical separations followed by appropriate counting. One-liter aliquots were used for all analyses except tritium and plutonium-neptunium. Most tritium analyses were performed by counting 10 ml in a gel system. A few samples were analyzed by electrolytic enrichment of 250 ml aliquots prior to counting. Plutonium and neptunium analyses were performed on 10-liter samples by a plutonium chemical separation method (*3*), modified to include neptunium, followed by alpha spectrometry. Plutonium-236 was used to determine the plutonium yield.

Argonne wastewater is discharged into Sawmill Creek, a small stream that runs through the laboratory grounds, drains surface water from much of the site, and flows into the Des Plaines River about 450 meters downstream

from the wastewater outfall. Sawmill Creek was sampled upstream from the Argonne site and downstream from the wastewater outfall to determine if radioactivity was added to the stream in Argonne wastewater or from surface drainage. The sampling locations are shown in figure 1. Below the wastewater outfall, the creek was sampled continuously, and the individual samples collected five times weekly. Since it was impractical to analyze all the samples for all the nuclides and elements desired, equal portions of the samples collected each week were combined and analyzed. The results obtained in this way represent the average concentrations in the weekly samples. Above the site, samples were collected twice a month and selected samples were analyzed for the same radionuclides as the below-outfall samples.

Annual summaries of the results obtained for Sawmill Creek are given in table 8. Comparison of the results, and 95-percent confidence limits of the averages, for the two sampling locations show that the only nuclides whose presence in the creek water can be attributed to Argonne operations were tritium, neptunium-237, plutonium-239, and possibly strontium-90. The fraction of individual samples containing activity attributable to Argonne was 90 percent for tritium and 50 percent for plutonium and neptunium. The concentrations of all four nuclides were quite low compared to the AEC standards. The principal radionuclide added to the creek by Argonne wastewater, in terms of both concentration and percent of AEC standard, was tritium. The average Argonne contribution of this nuclide to the creek amounted to only 0.02 percent of the AEC standard and the highest concentration in any single sample was equivalent to 0.02 percent of the AEC standard and the highest concentration in any single sample was equivalent to 0.06 percent of the AEC standard. The average tritiated water concentration in Sawmill Creek during the past few years shows Argonne's tritium contribution to have decreased by a factor of three over 1970 and by a factor of 20 over 1971, when a leak occurred in the CP-5 heat-exchanger. This is evidence of the laboratory's continuing effort to reduce emissions to the lowest possible levels. The tritium in the creek above the site (270 pCi/liter) was similar in concentration to levels found away from the laboratory site and is characteristic of the pres-

Table 8. Radioactivity in Sawmill Creek water, Argonne National Laboratory, 1972

Radionuclide	Location	Number of samples	Concentration (pCi/liter)			Percent of AEC standard		
			Maximum	Minimum	Average	Maximum	Minimum	Average
Alpha (nonvolatile)	Upstream	24	2.8	1.1	2.0 ±0.18	(0.093)	(0.037)	(0.067)
	Downstream	253	3.8	0.64	1.6 ± .16	(.13)	(.021)	(.053)
Beta (nonvolatile)	Upstream	24	33	8.4	17 ±2.3	(1.1)	(.28)	(.57)
	Downstream	253	44	6.7	16 ±1.5	(1.5)	(.22)	(.53)
Tritium	Upstream	23	470	<200	270 ±45	.016	<.0067	.0090
	Downstream	253	1 870	205	565 ±70	.062	.0068	.019
Strontium-89	Upstream	10	<2			<.07		
	Downstream	200	<2			<.07		
Strontium-90	Upstream	10	1.4	<.5	.76 ± .25	.47	<.17	.25
	Downstream	200	2.0	<.5	1.1 ± .13	.67	<.17	.37
Iodine-131	Upstream	7	7.6	<3	<3.7	2.5	<1	<1.2
	Downstream	169	<3			<1		
Barium-140	Upstream	9	<2			<.007		
	Downstream	169	<2			<.007		
Uranium (natural)[a]	Upstream	13	2.4	.96	1.6 ± .21	(.0060)	(.0024)	(.0040)
	Downstream	253	2.7	.95	1.6 ± .14	(.0068)	(.0024)	(.0040)
Neptunium-237	Upstream	11	<.002			<.00007		
	Downstream	253	.15	<.002	.011 ± .0064	.005	<.00007	.00037
Plutonium-239	Upstream	11	<.0005			<.00001		
	Downstream	253	.035	<.0005	.0015 ± .0013	.00070	<.00001	.000030

[a] Uranium concentration in units of μg/liter can be obtained by multiplying the concentration given by 1.48 pCi/liter. The average concentration in the Creek then becomes 2.4 μg/liter.

ent normal levels of tritium in surface waters. During 1972, the tritium content of several Lake Michigan water samples was 275 to 280 pCi/liter. Over the past 2 years, the tritium concentration in surface water samples has decreased by a factor of 2 as the tritium from nuclear tests mixed with and was diluted by the hydrosphere.

The average total alpha and beta radioactivities were higher above the site, indicating that at times Argonne wastewater contained less nonvolatile activity than creek water. The higher activities above the site are probably due to the water added to the creek by a large municipal sewage treatment plant. The large amount of dissolved solids added in the sewage water is accompanied by a small amount of radioactive nuclides, and increases the radioactivity in natural creek water. The total alpha and beta radioactivities were not appreciably different than in 1971.

In addition to the natural beta radioactivity and that added by wastewater below the outfall, beta radioactivity from nuclear detonations was detected at both sampling locations. The normal nonvolatile beta radioactivity is approximately 10 pCi/liter. It is estimated that fallout activity added about 5 pCi/liter to the nonvolatile beta activity at both locations and that the Argonne contribution below the outfall averaged about 1 pCi/liter equivalent to 0.03 percent of the AEC standard. The Argonne contribution remained the same as 1971 levels, while the fallout contribution decreased by about a factor of 2.

The same nuclides added to the creek in Argonne wastewater are also produced in nuclear detonations and are constituents of fallout (although some are not present in amounts above the detection limits). The total concentration, regardless of source, must be used in assessing the health hazard of a radionuclide not naturally present, and the percent of the AEC standards for all nuclides listed in table 8 were very low.

Since Sawmill Creek empties into the Des Plaines River, which in turn flows into the Illinois River, the radioactivity in the latter two streams is important in assessing the contribution of Argonne wastewater to the environmental radioactivity. The Des Plaines River was usually sampled twice a month below and monthly above the mouth of Sawmill Creek to determine if the radioactivity in the creek had

Table 9. Radioactivity in Des Plaines River water, Argonne National Laboratory, 1972

Radionuclide	Location	Number of samples	Concentration (pCi/liter)			Percent of AEC standard		
			Maximum	Minimum	Average	Maximum	Minimum	Average
Alpha (nonvolatile)	Upstream	11	3.4	0.82	1.8 ± 0.39	(0.11)	(0.027)	(0.060)
	Downstream	24	3.1	.85	1.8 ± 0.22	(.10)	(.028)	(.060)
Beta (nonvolatile)	Upstream	11	43	5.1	18 ± 6.2	(1.4)	(.17)	(.43)
	Downstream	24	24	4.9	11 ± 2.0	(.80)	(.16)	(.37)
Tritium	Upstream	11	352	<200	245 ±45	.012	<.0067	.0082
	Downstream	24	378	<200	230 ±35	.013	<.0067	.0077
Strontium-89	Upstream	9	<2			.07		
	Downstream	17	<2			.07		
Strontium-90	Upstream	9	1.6	<.5	1.1 ± .29	.53	<.17	.37
	Downstream	17	2.0	.50	1.2 ± .22	.67	.17	.40
Iodine-131	Upstream	7	<3			<1		
	Downstream	14	3.0	<3	<3	1.0	<1	<1
Barium-140	Upstream	8	<2			<.007		
	Downstream	15	<2			<.007		
Uranium (natural)[a]	Upstream	10	2.1	.95	1.6 ± .21	(.0052)	(.0024)	(.0040)
	Downstream	23	3.1	.40	1.6 ± .27	(.0078)	(.0010)	(.0040)
Neptunium-237	Upstream	11	<.002			<.00007		
	Downstream	10	<.002			<.00007		
Plutonium-239	Upstream	11	.0014	<.0005	.00072 ± .00027	.000028	<.00001	.000014
	Downstream	10	.00092	<.0005	.00055 ± .00017	.000018	<.00001	.000011

[a] Uranium concentrations in units of μg/liter can be obtained by multiplying the concentration given by 1.48. The average concentration is 2.4 μg/liter.

any effect on the activity in the river. Annual summaries of the results obtained for these two locations are given in table 9. The concentrations were in their normal ranges. The natural nonvolatile beta activity in the river is 5 to 10 pCi/liter, and the excess, 4 to 5 pCi/liter was due to fallout.

Evidence of fission product fallout is apparent in some of the water samples. Positive iodine-131 concentration in the Des Plaines River and at 15K in Sawmill Creek on the same day in early May correlate with air filter results that indicated a recent atmospheric nuclear test. Between June and October, plutonium-239 was detected at both locations in the river. Since the river consists mainly of surface runoff water, the presence of the plutonium-239 can be attributed to fallout, carried down by the rains and collected in the river. The fact that plutonium-239 could not be found at any time in Sawmill Creek above the site is due to the fact that a substantial portion of this water is from deep municipal wells.

The activities in samples of Illinois River water (table 10) were similar to those found in other bodies of water in the area and to the activities found previously at these same locations. The average alpha concentration of 1.2 pCi/liter and average beta concentration of 8.5 pCi/liter of 31 offsite surface water samples collected during the year is evidence that the Illinois River activity levels are normal. No radioactivity originating at Argonne could be detected in the Des Plaines or Illinois Rivers.

Soil, grass, and benthic materials

Plutonium deposition in soil, grass, and benthic materials was measured on and off the site to study the plutonium fallout level in the area from nuclear testing and to determine if any plutonium is present in the environment that might be due to Argonne operations. Soil samples consisted of a core 173 cm^2 in area of 30 cm deep. The grass samples were obtained by collecting all the grass from a 1 m^2 area. A grab sampling technique was used to obtain benthic materials. After drying, grinding, and mixing, 100 gram portions of soil and benthos were analyzed. The size of the grass samples was 40 g of the oven-dried plant.

The onsite and offsite soil results are given in tables 11 and 12, respectively. The limits given for the individual results are the statistical counting errors at the 95-percent confidence level, while the limits of the averages are the 95-percent confidence levels calculated from the standard deviation of the average. Comparison of the onsite and offsite samples shows that the same average and general range of concentrations exist in all areas for both plutonium isotopes, and it may be concluded that the plutonium in the onsite samples resulted primarily from fallout of debris from nuclear detonations. Fallout deposition values found by other laboratories (*4–6*) are in the same range as those reported here, namely about 2 nCi/m^2.

Several onsite locations are slightly higher than the highest offsite sample. These samples

Table 10. Radioactivity in Illinois River water, ANL, 1972

Location	Date collected	Concentration (pCi/liter)					
		Alpha (nonvolatile)	Beta (nonvolatile)	Tritium	Uranium [a]	Neptunium-237	Plutonium-239
McKinley Woods State Park	June 27	1.2	9.7	390	0.61	<0.001	<0.0005
Below Dresden Power Station	June 27	1.2	7.4	285	1.1	<.001	<.0005
Morris	June 27	1.0	8.2	315	.68		
McKinley Woods State Park	October 5	1.1	8.4	290	1.5	<.0005	[b].00053
Below Dresden Power Station	October 5	.57	5.3	290	1.1	<.0005	[b].00022
Morris	October 5	.32	6.6	280	1.0		
Starved Rock State Park	October 5	.70	6.6	245	1.3		

[a] Uranium concentrations in units of μg/liter can be obtained by multiplying the concentration given by 1.48.
[b] These analyses were made on a 45-liter sample; all other plutonium analyses were made on 10-liter samples.

Table 11. Plutonium concentrations in onsite soil, ANL, 1972

Date collected	Location [a]	Plutonium-238		Plutonium-239		$^{238}Pu/^{239}Pu$
		(fCi/g)	(nCi/m²)	(fCi/g)	(nCi/m²)	
June 7:	12L	0.34±0.24	0.13±0.086	4.5±0.5	1.74±0.20	0.075
	12L	.61± .48	.26± .20	6.7±1.1	2.84± .47	.092
	12L	.79± .30	.24± .088	5.6± .6	1.70± .18	.14
	12L	.51± .24	.23± .10	3.9± .5	1.74± .21	.13
	12F	.56± .25	.25± .11	3.3± .5	1.45± .20	.17
	12–13F	.54± .26	.23± .10	3.7± .5	1.50± .20	.15
	9H	.35± .24	.13± .083	4.8± .5	1.77± .20	.073
June 8:	9I	.42± .24	.16± .085	8.0± .7	3.09± .27	.052
	11I	.41± .24	.16± .085	4.7± .5	1.77± .20	.090
	11I	.71± .27	.30± .12	3.8± .5	1.63± .22	.18
June 13:	11I	.79± .26	.26± .083	7.5± .6	2.47± .20	.10
	11I	.71± .29	.29± .12	5.5± .6	2.25± .25	.13
October:	11H	1.3 ± .29	.34± .077	6.0± .5	1.66± .16	.20
	11H	1.3 ± .30	.35± .083	9.4± .7	2.50± .19	.14
	11H	.43± .23	.15± .073	4.8± .5	1.66± .17	.090
	11H	.54± .24	.11± .046	6.1± .6	1.29± .12	.085
	11H	.52± .24	.17± .071	4.8± .6	1.53± .19	.11
	11H	.97± .29	.16± .048	8.7± .7	1.44± .11	.11
October 30:	11H	.75± .29	.21± .077	4.5± .5	1.27± .15	.17
	11H	.63± .28	.25± .10	7.3± .7	2.87± .26	.087
	11H	1.0 ± .30	.28± .083	8.1± .7	2.24± .19	.12
	12H	.55± .23	.19± .071	3.2± .4	1.11± .13	.17
	12H	.78± .29	.26± .095	4.2± .5	1.40± .17	.19
	12G	.59± .23	.20± .071	2.7± .4	.90± .13	.22
Average			0.22±0.027		1.83±0.24	0.12

[a] The locations are given in terms of the grid coordinates in figure 1.

Table 12. Plutonium concentrations in offsite soil, ANL, 1972

Location	Date collected	Plutonium-238		Plutonium-239		$^{238}Pu/^{239}Pu$
		(fCi/g)	(nCi/m²)	(fCi/g)	(nCi/m²)	
McKinley Woods State Park	June 27:	0.31±0.24	0.08±0.06	3.9±0.5	1.10±0.14	0.07
Pioneer Park, Naperville		.68± .25	.26± .10	4.0± .6	1.50± .21	.17
Saganashkee Slough		.59± .26	.20± .09	6.3± .6	2.09± .21	.09
McGinnis Slough	September 27:	.78± .46	.31± .19	4.8± .8	1.96± .31	.16
McCormick Woods		.43± .21	.15± .07	4.6± .5	1.55± .17	.09
Lake Delavan, Wisconsin	October 3	.48± .23	.14± .06	5.8± .5	1.58± .16	.08
Average			0.19±0.07		1.63±0.29	0.12

were collected near buildings in which plutonium had been used, so the possibility of plutonium in their vicinity exists. The levels of activity in these samples are not sufficiently above the fallout range to allow an unequivocal conclusion. Surveillance in these areas is continuing.

The samples collected downwind from Building 205 after the glove box explosion averaged 1.83 nCi/m² and ranged from 1.1 to 2.9 nCi/m². These values are also not sufficiently different from the offsite results to conclude with good probability that the samples contained plutonium from the explosion.

Composite monthly precipitation samples were analyzed for plutonium-239 by the same procedure as used on water samples. Concentrations, expressed in terms of ground deposition, ranged from 0.12 to 0.75 pCi/m² and averaged 0.4 pCi/m². The total 1972 deposition by precipitation was only 0.3 percent of the amount previously deposited, and implies that, in the absence of further testing, the soil content will not increase greatly.

The thorium and uranium content of the soil samples was also measured, the former by chemical separation and alpha spectrometry and the latter by a fluorophotometric method. The thorium-228 concentrations averaged 0.40 ± 0.04 pCi/g onsite and 0.43 ± 0.10 pCi/g offsite. The thorium-230 averaged 0.47 ± 0.04 pCi/g onsite and 0.45 ± 0.10 pCi/g offsite. The thorium-232 averaged 0.34 ± 0.03 pCi/g onsite and 0.37 ± 0.08 pCi/g offsite. No sig-

nificant differences between on- and offsite concentrations were found. These are normal levels of the naturally-occurring thorium activities. Results of uranium analyses averaged 1.5 ± 0.2 pCi/g onsite and 1.3 ± 0.3 pCi/g offsite, and are quite similar to levels of uranium in soil found in previous years in this area (*7,8*). No evidence of uranium from Argonne was found. In terms of mass, the thorium concentrations were 3.1 μg/g onsite and 3.3 μg/g offsite and the uranium concentrations were 2.2 μg/g onsite and 1.9 μg/g offsite. Gamma-ray spectrometric analysis of these soil samples showed only traces of old fission products attributable to fallout, and no activity related to laboratory operations.

The results of plutonium-239 measurements in grass are given in table 13. The concentrations in terms of area were approximately the same on and off the site. Two onsite samples (June 7, 12L and 9I) are 1.5 to 2 times higher than the offsite samples, and these were collected near soil that also contained above average plutonium concentrations. However, it is not certain that any of the plutonium in these samples can be attributed to Argonne since grass collected in 1971 contained still higher concentrations both on and off the site (*9*) than were found this year. The differences observed are probably due to normal variations in fallout concentrations. In terms of deposition, the plutonium-239 concentration was a factor of 2000 to 5000 less than in soil from the same location. Uranium concentrations were similar to those reported last year (*10*).

Table 13. Plutonium-239 concentrations in grass, ANL, 1972

Location [a]	Date collected	Plutonium-239 concentration	
		(fCi/g)	(pCi/m²)
Onsite:			
12L	June 7:	2.3 ±0.7	0.46 ±0.14
12–13L		1.5 ± .4	.22 ± .07
9I	June 8:	4.2 ± .8	.67 ± .12
12I		1.6 ± .5	.35 ± .12
12H	October 17:	8.5 ±4.6	.33 ± .19
12H		4.5 ±3.7	.21 ± .18
12H	October 18:	4.4 ±1.7	.22 ± .08
12H	October 30:	2.3 ±1.6	.32 ± .21
Offsite:			
McKinley Wooda State Park	June 27:	.87 ± .3	.17 ± .07
Lake Delavan, Wis	October 3:	2.8 ±1.9	.29 ± .19

[a] The onsite locations are given in terms of the grid coordinates in figure 1.

A study was made of the plutonium concentration in the Sawmill Creek bed below the laboratory wastewater outfall. The results are shown in table 14 along with the results from several control locations. Because the nature of the creek bottom prevented collection from a known area, results are expressed in terms of concentration rather than deposition. The lower concentrations (<10 fCi/g) were found in samples collected in areas where the flow rate is rapid and the bed was sandy and had little absorptive capacity. As the creek slows 90 meters below the outfall, the sedimentation increases, the bed becomes more silty and retentive, and higher plutonium concentrations occur. The highest creek results are similar to those of the slower moving Des Plaines River. Thorium and uranium concentrations in the creek bed followed the same pattern. Little, if any, plutonium released in the laboratory wastewater is retained by the creek bottom.

Table 14. Plutonium concentrations in benthic material, ANL, 1972

Location [a]	Concentration (fCi/g)		$^{238}Pu/^{239}Pu$
	Plutonium-238	Plutonium-239	
Des Plaines River, Willow Springs	1.7 ±0.3	21.8 ±1.1	0.078
Des Plaines River, Lemont	2.1 ± .4	33.3 ±1.3	.063
15K	1.1 ± .3	7.2 ± .6	.15
45 meters below 7M	1.1 ± .3	9.7 ± .8	.11
90 meters below 7M	1.3 ± .3	18.4 ±1.0	.071
140 meters below 7M	2.7 ± .4	25.9 ±1.3	.10
180 meters below 7M	2.2 ± .4	27.7 ±1.3	.079
230 meters below 7M	2.1 ± .4	32.0 ±1.4	.066
270 meters below 7M	2.0 ± .4	25.1 ±1.2	.080
370 meters below 7M	2.5 ± .4	24.0 ±1.2	.10
Mouth of Sawmill at Des Plaines	3.0 ± .4	34.2 ±1.4	.088

[a] Location 15K is above the ANL site. Location 7M is below the wastewater outfall. Both locations are in Sawmill Creek.

Radioactivity in milk

Raw milk was collected monthly from a local dairy farm and analyzed for several fission products. Barium-140, strontium-89, and iodine-131 were not present in concentrations greater than the minimum detectable amounts of 20 pCi/liter for iodine-131 and 2 pCi/liter for the other two nuclides. The cesium-137 and strontium-90 concentrations are given in table 15. These two nuclides are long-lived fission

Table 15. Cesium-137 and strontium-90 concentrations in milk, ANL, 1972

Date collected	Concentration (pCi/liter)	
	Cesium-137	Strontium-90
January 5	NS	4.0
February 2	<10	6.0
March 1	10	2.2
April 5	13	8.2
May 3	14	6.5
June 7	<10	6.9
July 5	<10	5.3
August 2	<10	4.8
September 6	<10	3.8
October 4	<10	3.9
November 1	<10	4.0
December 6	<10	4.7
Average	<11	5.0

NS, no sample.

products from past nuclear tests and their presence in milk is not related to Argonne operations. The average strontium-90 content decreased by 10 percent from last year, while the cesium-137 concentrations decreased about 30 percent.

The concentrations given in table 15 may be compared to the AEC standards for drinking water. These values are 300 pCi/liter for strontium-90 and 20 nCi/liter for cesium-137 if the daily intake of water is 2.2 liters. The consumption of 1 liter of milk per day would then result in an average intake of 0.75 percent of the strontium-90 and <0.025 percent of the cesium-137 AEC standards. Using the standards specified by the Federal Radiation Council, 1 liter of milk is equivalent to <0.3 and 2.5 percent of the daily intake guides for cesium-137 and strontium-90, respectively.

Penetrating radiation

Measurements of gamma-ray dose were made with thermoluminescent dosimeters (extruded calcium fluoride chips, dysprosium-activated) calibrated with an NBS standard radium-226 source. Each measurement was the average of 3 to 6 chips exposed in the same package. Exposure times ranged from 44 to 74 days (except for one 133-day exposure). Individual results were calculated in terms of annual dose rate, and these were weighted according to their exposure times in calculating the average for a location.

The measurements were made throughout the year at a number of locations at the site security fence to determine the dose that might be due to Argonne operations at the closest uncontrolled approach to the laboratory. The actual site boundary varies from 140 to 1400 meters from the security fence, and over most of the perimeter is at least 450 to 900 meters from the fence. The closest public access to potential radiation sources is at coordinate 8H. At this location, the public is allowed to visit a preexisting cemetery (St. Patrick's Cemetery). Measurements were also made at several locations on the site within the fence, and at several offsite locations for comparison purposes. The results are given in tables 16, 17, and 18 for the offsite, ANL site security fence, and onsite locations, respectively.

The offsite measurements were quite uniform both by location and by period. Ninety-five percent of the results were in the range from 94 to 114 mrem/year. Only one anomalous result was obtained, 121 mrem/year for the second measurement at Lombard; all other results fell within 2 standard deviations (95-percent confidence limits) of the average for a single result, 105 ± 11 mrem.

Table 16. Environmental penetrating radiation at offsite locations, ANL, 1972

Location	Period of measurement	Days	Dose rate (mrem/yr)
Downers Grove	2/17- 4/29 (2)	72	106
	5/12- 6/29 (2)	48	96
	6/29- 9/11	74	103
	7/ 6- 9/11 (6)	67	111 ± 9
	9/11-11/21	71	112
	11/21- 1/ 5	45	105
Average			106 ± 11
Woodridge	2/17- 5/ 1	74	109
	9/ 8-11/21	74	105
	11/21- 1/ 4	44	103
Average			106 ± 3
Lemont	2/17- 5/ 1	74	103
	6/29- 9/ 7	70	105
	9/11-11/21	71	101
Average			103 ± 8
Lombard	6/29- 9/ 8	71	107
	11/21- 1/ 5	45	121
Average			112
Naperville	6/29- 9/ 8	71	94
Hinsdale	7/ 5- 9/ 8	65	114
Plainfield	11/21- 1/ 4	44	103
Oak Lawn	9/ 8-11/21	74	98
	11/21- 1/ 4	44	102
Average			99
Overall average			105 ± 5

Table 17. Environmental penetrating radiation at ANL site security fence, 1972

Location	Period of measurement	Days	Dose rate (mrem /yr)
13D:	2 /17– 4 /29	72	76
	7 / 5– 9 /11	68	85
Average			81
14I:	2 /17– 4 /29	72	109
	9 / 8–11 /21	74	111
	11 /21– 1 / 4	44	122
Average			113 ± 14
18J	6 /29– 9 / 8	71	100
14L:	2 /17– 5 / 1	74	104
	7 / 5– 9 / 8	65	101
	9 / 8–11 /21	74	100
Average			102 ± 4
12–O:	2 /17– 4 /29	72	108
	5 /12– 6 /29	48	98
	6 /29– 9 / 8	71	108
Average			105 ± 11
12N:	6 /29– 9 / 8	71	98
	9 / 8–11 /21	74	107
Average			103
10M	11 /21– 1 / 4	44	111
10L	2 /17– 4 /29	72	111
7I:	6 /29– 9 /11	74	350
	9 /11–11 /21	71	509
Average			428
8G:	2 /17– 4 /29	72	131
	5 /12– 6 /29	48	111
	6 /29– 9 /11	74	123
	9 /11–11 /21	71	134
	11 /21– 1 / 4	44	139
Average			128 ± 21
8F:	2 /17– 4 /29	72	121
	5 /12– 6 /29	48	108
	6 /29– 9 / 8	71	110
	9 / 8–11 /21	74	116
	11 /21– 1 / 4	44	111
Average			114 ± 10
9EF:	2 /17– 4 /29	72	114
	5 /12– 6 /29	48	112
	6 /29– 9 / 8	71	112
Average			113 ± 2
10E:	2 /17– 6 /29	133	98
	9 / 8–11 /21	74	111
Average			103

Table 18. Environmental penetrating radiation on the ANL site, 1972

Location	Period of measurement	Days	Dose rate (mrem /yr)
9H—75 m east of CP–5	2 /17– 4 /29	72	1 900
	6 /29– 9 / 8	71	1 200
	9 / 8–11 /21	74	435
	11 /21– 1 / 4	44	1 640
Average			1 250
9G—75 m west of CP–5	6 /29– 9 / 8	71	346
	9 / 8–11 /21	74	452
8H—Heliport	2 /17– 4 /29	72	149
	7 / 5– 9 /11	68	133
7I—North fence of waste storage area	2 /17– 4 /29	72	1 270
	5 /12– 6 /29	48	1 170
	6 /29– 9 / 8	71	864
	11 /21– 1 / 4	44	2 360
Average			1 330
7I—Waste storage area	5 /12– 6 /29	48	860
	11 /21– 1 / 4	44	2 360
7I—West fence of waste storage area	9 /11–11 /21	71	496
Average			1 105
10I—Bluff Road, NW of ZGS	5 /12– 6 /29	48	106
	6 /29– 9 / 8	71	108
9H—North of building 315, 225 m south of CP–5	6 /29– 9 / 8	71	248
	11 /21– 1 / 4	44	290
7–8J—NW of storage area	5 /12– 6 /29	48	125
	6 /29– 9 /11	74	135
11H—South of 205, 500 m north of CP–5	5 /12– 6 /29	48	102
	6 /29– 9 / 8	71	115
9J—ZGS area, south	7 / 5– 9 /11	68	109
	9 / 8–11 /21	74	113
	9 /11–11 /21	71	120
Average			114
9K—ZGS area, east of Meson building	9 / 8–11 /21	74	131
	11 /21– 1 / 4	44	188
13I—Building 202 parking lot	2 /17– 4 /29	72	78
14I—Building 202, south	6 /29– 9 / 8	71	118
13I—Building 202, north	6 /29– 9 / 8	71	89
Average			95
13H—Building 203, north	9 / 8–11 /21	74	122
	11 /21– 1 / 4	44	119
13G—Building 206, west	9 / 8–11 /21	74	97

If it is assumed that the offsite readings accurately represent the average natural radiation background of the area, a result between 94 and 116 mrem/year may be considered normal with a 95 percent probability. Only 2.5 percent of the measurements of a natural background radiation field should be higher than 116 mrem/year and 2.5 percent lower than 94 mrem/year. The offsite average, 105 mrem/year, is almost identical with that obtained in 1971, 104 mrem/year.

Examination of the site security fence measurements (table 17 and figure 3) show that only three locations gave average readings outside the normal range and two locations occasionally gave readings outside the normal range. The latter finding can simply be part of the normal spread indicated above. The dose rate at location 13D was well below the normal range, as it was in 1971, probably because of the large amount of subsurface gravel in the area containing below average concentrations of natural activities. Two locations were above normal, 8G and 7I, both on the south security fence. The abnormal dose rate at 7I, approximately 300 mrem/year, was due to radioactive materials in a radioactive waste storage area several hundred meters north of the fence.

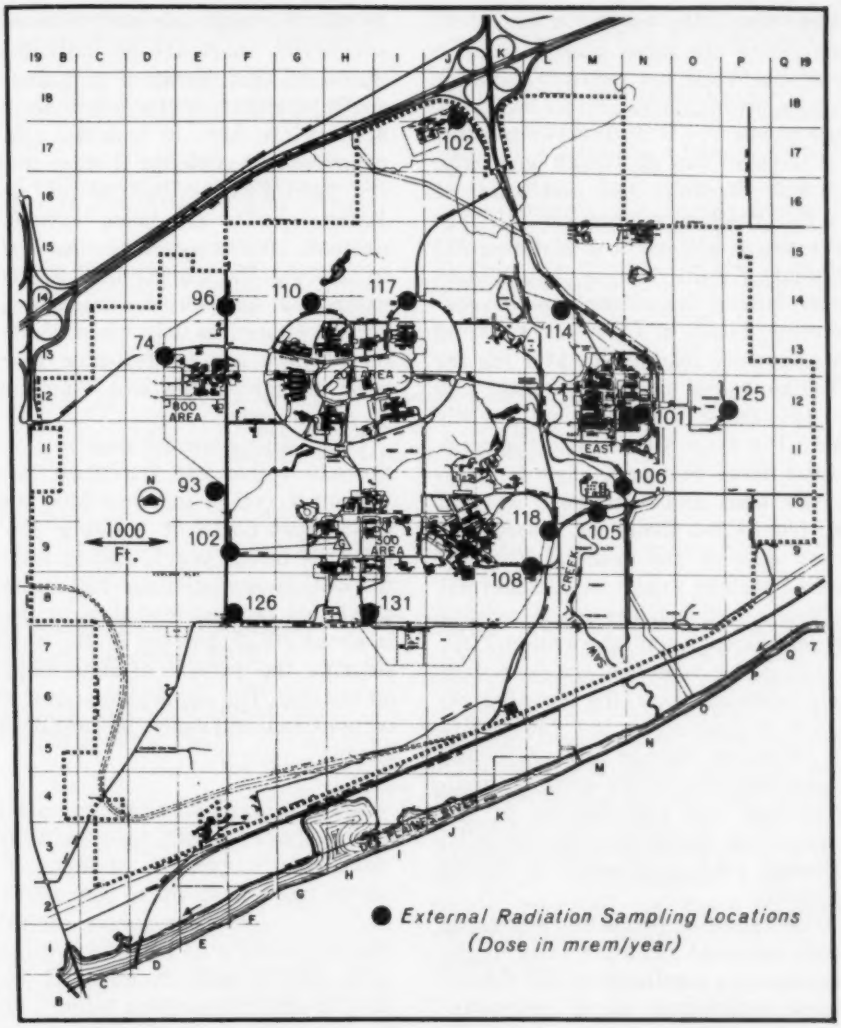

Figure 3. External radiation measurements, Argonne National Laboratory

Radioactive waste is stored and packaged in this area for shipment to waste burial sites elsewhere. Readings in the center of the storage area (table 18) were as high as 2.3 rem/year. The area between the site security fence and the site boundary in this vicinity is rugged and heavily wooded, and the land rises steeply from the Des Plaines River. As a result, the area is relatively inaccessible and no individuals frequent this location. Based on measurements made north and west of the storage area, the dose rate at the south boundary line, about 590 meters from the fence, would be indistinguishable from background levels. The waste storage area may be considered as a stationary gamma-ray source in considering the variation of dose with distance. The strength of the source varies, however, as material is moved in and out of the area.

The dose rate at 8G, 128 mrem/year, is about

20 mrem/year above the normal average. At this location, there are three possible sources for above-normal readings; direct radiation from the waste storage area, direct radiation from the low power (10 W to 10 kW) reactors and from a tandem Van de Graaff generator in Building 315 (location 9H) and argon-41 from the CP-5 reactor at location 9H. The abnormal reading at 9H, north of Building 315 (264 mrem/year) (onsite) makes this building a possible, but minor, contributor to the dose at 8H. The contribution of CP-5 is considered negligible since onsite readings at 11H (as far north of CP-5 as the 8H location is south) and at location 10I (west of CP-5 and slightly farther from CP-5 than 8H) were all normal. The wind roses from this area show a maximum from the west and southwest, so that higher doses from CP-5 should be observed to the north and east of the reactor. Elevated readings were obtained onsite at location 8H (141 mrem/year), between the waste storage area and the 8G location and at location 7/8J, but to the east. These readings are consistent with the interpretation that the elevated 8G reading is due primarily to the radioactive materials in the waste storage area. Although additional measurements in the area are indicated to determine the contribution of the various sources to the dose at 8G unequivocally, the waste storage area is believed to be the major contributor.

The applicable radiation protection standards for whole body external radiation dose to the general population is a maximum of 500 mrem/year to critical individuals, or, if individual doses are not known, 170 mrem/year to a suitable sample of the exposed population. The latter criterion assumes that the maximum dose to individuals in the sample will not exceed the average by more than a factor of 3 (*11*). The dose from Argonne operations at location 8G (about 20 mrem/year) is well within these limits, particularly since the individuals visiting the cemetery are exposed for only a very small fraction of the year. The dose at the fence line south of the waste storage area, about 300 mrem/year, is 60 percent of the 500 mrem/year limit to individuals, although it is about twice the 170 mrem limit to the "suitable sample." However, as noted previously, there are no individuals being exposed at that location, and the dose at the south boundary of the site is normal. It is also appropriate here to consider the "as low as practicable" guideline limits being proposed for light-water cooled power reactors (*12*). Various limits are being considered, and at present, 10 mrem/year is the one most likely to emerge. The annual dose at 8G exceeds this value, but as pointed out earlier, individuals receive exposures only when visiting the cemetery. There are no full-time residents living close enough to the site boundary to receive 10 mrem/year.

Other above-normal readings of interest on the site (table 18) are those 70 meters east (1.3 mrem/year) and west (400 mrem/year) of CP-5; just north of building 315 at location 9H (264 mrem/year), and at 9K, just east of the ZGS Meson building (152 mrem/year). The maximum occupational dose at these locations is about 20–25 percent of the anual dose considering the amount of time employees spend on the site. The applicable annual standard for occupational exposure is considerably higher, 5 rem.

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Previous coverage in *Radiation Data and Reports:*

Period	Issue
January–December 1971	May 1973

2. Bettis Atomic Power Laboratory [4] January–December 1972

Westinghouse Electric Corporation
Pittsburgh, Pa.

The Bettis Atomic Power Laboratory is operated by the Westinghouse Electric Corporation for the U.S. Atomic Energy Commission (AEC) and is engaged in the design and development of nuclear power reactors.

The laboratory is situated on a 200 acre tract of land in the Borough of West Mifflin, Pa., approximately 7 miles southeast of the city of Pittsburgh. A map of the Bettis Laboratory and surrounding area is provided in figure 4.

This document summarizes the results of the effluent and environmental monitoring program conducted at the laboratory for January–December 1972. The program has been continuously maintained since 1959 and regulates the disposal of solid, liquid and airborne effluents from the laboratory. Since its inception, the data obtained from this program have shown that the laboratory's procedures for controlling effluents are adequate to ensure that all releases to the environment are made in accordance with the applicable requirements. The program includes sampling and analysis of exhaust air, liquid effluents, and silt and water samples from the small streams on the laboratory site and in the nearby area. Evaluation of these data, along with the analysis of the environmental radiation measurements, provides the basis for assessing the environmental impact due to laboratory operations.

Monitoring of liquid effluent

The Bettis Atomic Power Laboratory consists of a main laboratory area and a critical facilities area. Liquid effluent from these areas consists of uncontaminated coolant and process water (e.g., air conditioning coolant), surface runoff rainwater, and controlled liquid releases whose measured radioactivity concentrations are less than the applicable discharge limit of 300 pCi/liter. The liquid discharge limit applicable to laboratory releases is conservatively based on the maximum permissible concentration of strontium-90 in water.

[4] Summarized from Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, WASH–1259 "Bettis Atomic Power Laboratory for 1972".

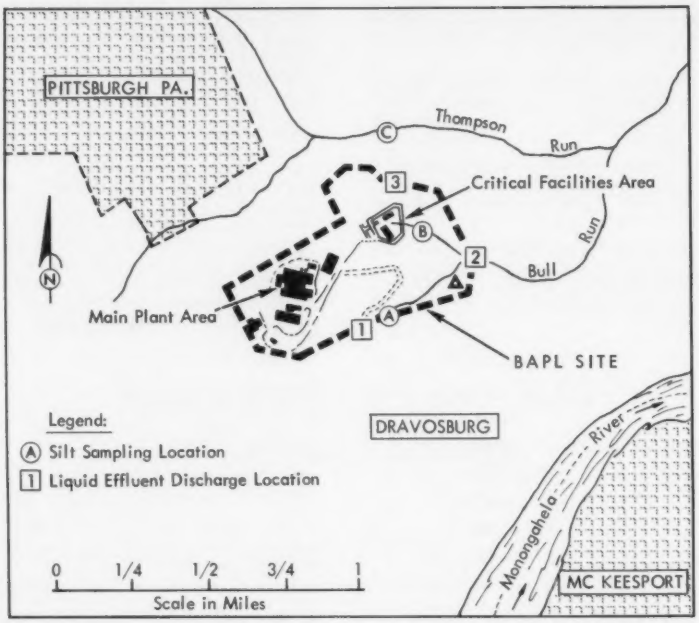

Figure 4. Bettis Atomic Power Laboratory sampling stations

Effluent sampling

Process liquids resulting from laboratory operations in which radioactive materials are handled are collected in holding tanks. Water is released to the environment only when the measured activity is less than the AEC standards. Liquid effluents having a concentration of radioactivity in excess of the AEC standards are treated either by evaporation or ion exchange and filtration. Water from the holding tanks is sampled and analyzed for gross alpha and gross beta-gamma activity to determine if further treatment is needed or if the water has a low enough concentration of radioactivity to release. The residue from the liquids which are evaporated is solidified and shipped offsite for burial as solid waste.

Samples of laboratory liquid effluents were collected and analyzed to ensure that all applicable water quality standards were met.

Analytical techniques

Samples are prepared for analysis by evaporating 100 ml aliquots of process liquid to deposit suspended and dissolved solids on 5-cm aluminum planchets. Alpha and beta-gamma measurements are obtained on an automatic sample counter.

The automatic sample counter uses a gas flow, 2π proportional counter with a surrounding NaI(Tl) crystal in anticoincidence to reduce the background radiation detected by the proportional counter. The combination of the guarded sample detector and extensive lead shielding permits the unit to maintain low background count levels. Calibrations for the counter are performed using plutonium-239 (alpha) and cesium-137 (beta-gamma) standard sources. The minimum detectable levels for alpha and beta-gamma radioactivity are 5.0 pCi/liter and 10 pCi/liter, respectively.

All analyses for water quality parameters were performed by a subcontractor utilizing standard laboratory techniques described in reference (*13*).

Effluent monitoring results

The net radioactivity released from the laboratory during January–December 1972 amounted to a quantity that was not significantly different from the waste discharge permit quantity of 0.0011 curie. During this period, the total liquid effluent volume from the Bettis site, including surface runoff rainwater and process waters, was 220.5×10^6 gallons. Hence, the net average radioactivity concentration of the liquid effluent released to the environment was 1.31 pCi/liter or 0.44 percent of the AEC standard. The radioactive constituents contained in the liquid effluent which are attributable to laboratory operations are strontium-90, cesium-137, and cesium-134.

Monitoring of airborne effluent

All of the laboratory stacks which exhaust air from areas where radioactive materials are handled are monitored on a continuous basis. A daily sample of stack effluent particulate matter is collected for analysis on filter paper at a sampling flow rate of 20 liters per minute. At two locations where the potential for iodine-131 releases can exist, sampling of iodine-131 concentrations is also performed by utilizing charcoal-impregnated cellulose filters.

Until April 1972, the filters were counted for alpha and beta-gamma radioactivity using alpha scintillation and end-window Geiger-Mueller detectors, respectively. The minimum detectable levels for particulate alpha and beta-gamma radioactivity were 0.1 pCi/m^3 and 1.0 pCi/m^3, respectively. The alpha detector was calibrated with a thorium-230 standard source, and this Geiger-Mueller counter was standardized using cesium-137. Since April 1972, the filters have been counted on an automatic sample counter. This system has been calibrated for counting the alpha and beta-gamma activity deposited on filters using a thorium-230 standard source for alpha activity and cesium-137 for beta-gamma activity. The minimum detectable activities with the improved detector have decreased to 1.5 fCi/m^3 alpha and 11.0 fCi/m^3 beta-gamma.

The iodine-131 is counted with an end-window Geiger-Mueller counter. The minimum detectable activity for iodine-131 is 500 pCi/m^3. Calibration is performed with a cesium-137 standard.

Although the techniques used to measure the concentration of particulate radioactivity in air are sensitive to levels well below natural background, the radioactivity levels in most of the air exhausted from the laboratory were less than the minimum detectable level. In such cases, conservative calculations which assume that the air discharged contained particulate radioactivity at the minimum detectable level were used. The results indicate that less than 0.024 curie was released to the atmosphere in 1972. On this basis, the average concentration of airborne particulates in the air released was less than 5.7 percent of the AEC radiation standards for an unknown mixture of radionuclides in air. The general public outside the boundary of the laboratory was not exposed to radiation levels in excess of natural background, and the quantity of airborne radioactivity released was too small to have had any significant effect on the quality of the human environment.

Surface water monitoring

The principal purpose of the surface water sampling program is to provide additional assurance that the laboratory procedures for the control of radioactivity are adequate. The net amount of radioactivity measured in the laboratory effluents is compared with the net difference between the natural radioactivity in the city drinking water and precipitation and the radioactivity in surface water leaving the site. Samples of the water are analyzed for gross alpha and gross beta-gamma radioactivity.

The Bull Run sampling station collects approximately 50 ml aliquots of effluent water from a basin which is automatically siphoned and refilled at a rate proportional to the effluent flow. The number of aliquots is counted by a

Table 19. Summary of the surface water monitoring program, BAPL, 1972

Parameter	Number of samples	Concentration (pCi/liter)			Volume (gallon × 10^6)	Total activity (Ci)
		Maximum	Minimum	Average [a]		
Effluent	62	17.9	2.3	14.2±1.4	[b] 220.5	0.0118±0.0012
Influent	12	10.0	3.3	5.9±1.2		.0049± .0010
Precipitation runoff	12	91.9	6.8	28.6±7.1	[c] 47.26	.0051± .0013
Residual (effluent less influent and precipitation)						.0018± .0020

[a] At 95-percent confidence level.
[b] Measured at the Bull Run sample station.
[c] Assumes that precipitation runoff from 80 percent of roofs and paved grounds enters the laboratory storm sewer network.

mechanical register which permits calculation of the total effluent volume.

The analytical techniques employed are the same as those used for effluent monitoring and the minimum detectable levels for the gross alpha and gross beta-gamma analyses are 5.0 pCi/liter and 10 pCi/liter, respectively.

The results of the surface water monitoring program are summarized in table 19. As noted in table 19, a release of 0.0018 ± 0.0020 curie due to laboratory operations is derived by subtracting the radioactivity measured in the effluent water supply and in the precipitation and surface runoff from the effluent radioactivity measurements. Comparison of this calculated radioactivity release with the activity computed by summing all releases authorized by the discharge permit (0.0011 curie) indicates that within the uncertainties of the measurement, there is no significant difference between the two values. These data confirm that the procedures used by the laboratory to control radioactivity are effective in protecting the environment.

Dosimetry monitoring

Environmental radiation levels are monitored by 50 lithium fluoride thermoluminescent devices. Thirty-four of these devices are posted on the laboratory security fence at approximately 100-foot intervals. The remaining 16 are located at points on or near the laboratory

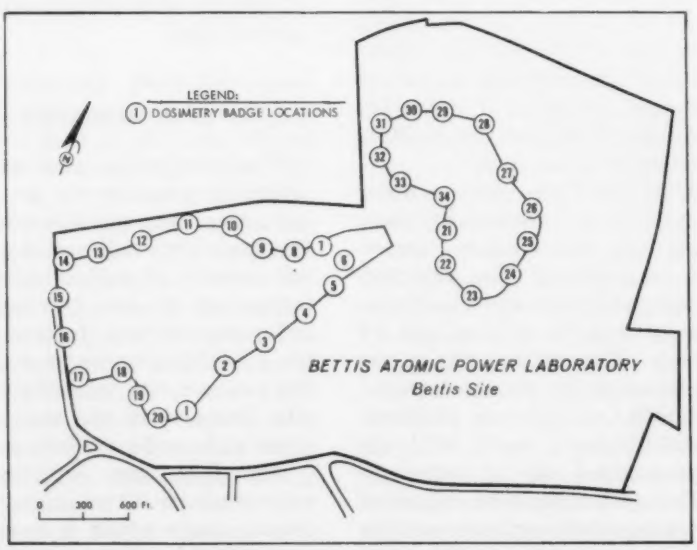

Figure 5. Dosimetry badge locations, BAPL

site boundary. The locations of the thermoluminescent monitors are shown in figure 5. In addition, nine control thermoluminescent dosimeter monitors are placed at locations remote from the laboratory site in order to provide independent measurements of local natural background radiation levels.

The onsite thermoluminescent monitors and the nine control monitors are processed quarterly. Calibration of the system is accomplished by readout of dosimeters exposed to a cesium-137 standard source.

A summary of quarterly environmental radiation dosimetry data, along with control dosimetry results, is given in table 20. It is concluded from this comparison that the radiation exposure to the general public at the site boundary was not above that received from natural background radiation.

Table 20. Environmental radiation measurements, BAPL, 1972

	Dose rate (mrem/calendar quarter)		
	Maximum	Minimum	Average [a]
Control	33.3	13.4	25.9
Site boundary	37.5	19.5	25.4

[a] Average values have a 30 percent deviation from the mean at the 95-percent confidence level.

Stream silt sampling

Silt samples are routinely collected from the three small streams on the laboratory site and from a remotely located control stream. A more extensive, improved, silt sampling liquid effluent and environmental monitoring program was implemented at the laboratory on October 1, 1972. The expanded sampling program increases the number of samples taken from Bull Run since it is the largest of the three streams on the site. It includes the collection and analysis of silt samples from several onsite and offsite locations. The revised sampling program is designed to provide increased confidence that laboratory operations have an insignificant effect on the environment.

In the new program, a total of 114 silt samples are collected annually from the control stream and the three streams which carry laboratory liquid effluents. The majority of these samples, 24 per quarter from 6 different sampling locations, are collected from Bull Run. Three samples are collected from each of the other three streams, semiannually. A total of 38 silt samples were collected annually from all locations prior to the implementation of the revised silt sampling program.

All of the silt samples collected are analyzed for gross alpha, gross beta-gamma and cesium-137 radioactivity.

The silt samples are oven dried, milled, homogenized and evenly distributed on a planchet. The gross radioactivity measurements are obtained by counting a 400 milligram sample for 100 minutes on a low background proportional automatic sample counter. Minimum detectable levels for these parameters are 4.0 pCi/g alpha and 1.4 pCi/g beta-gamma, although these values can vary to some degree due to self-absorption correction factors which are dependent on the exact sample weight. Self-absorption correction factors have been measured and are used when needed. Calibrations for this measurement are performed with uranium-235 (alpha) and cesium-137 (beta-gamma) standard sources.

Measurements of cesium-137 silt activity are obtained with a 3-inch diameter by 3-inch high NaI(Tl) scintillation detector. The average size of the silt samples for these measurements is 175 g. The system is calibrated with a set of dirt samples to which known amounts of a standard cesium-137 solution have been added. The cesium-137 concentration is calculated by integration of the 0.66 MeV photopeak area following subtraction of the Compton background continuum from higher energy gamma-rays. The minimum detectable activity for cesium-137 in silt varies from 0.45 pCi/g for a 100 g sample to 0.25 pCi/g for a 200 g sample.

Average radioactivity concentrations at the 95 percent confidence level of 8.3 ± 6.4 pCi/g alpha and 25.3 ± 2.8 pCi/g beta-gamma were measured in the control stream silt samples. The radioactivity measurements in the two streams which carry Critical Facility Area liquid effluents are not statistically different from the control stream values and are of no environmental significance.

Average net radioactivity concentration at the 95 percent confidence level of 4.6 ± 3.7 pCi/g alpha and 36.8 ± 15.7 pCi/g beta-gamma were measured over the initial 1.9 miles of Bull Run. The maximum and minimum net concentrations measured in Bull Run ranged from less than the minimum detectable level (4.0 pCi/g) to 10.5 pCi/g alpha, and from less than the minimum detectable level (1.4 pCi/g) to 66.4 pCi/g beta-gamma. The majority of this radioactivity is due to cesium-137, for which an average concentration of 33.2 ± 14.3 pCi/g was measured. The range on the cesium-137 concentrations measured in Bull Run silt was from 2.65 pCi/g to 54.10 pCi/g.

An analysis was performed for that portion of the stream in which levels of radioactivity above background were measured to determine the quantity of radioactivity present and its effect on the environment. For the purpose of the analysis, the average concentration of 36.8 ± 15.7 pCi/g beta-gamma radioactivity was conservatively assumed to be uniformly deposited over the topmost 2 inches of stream silt. Using this assumption, this analysis indicates that after 23 years of laboratory operations, the total accumulated activity in silt is less than 0.01 curie. Even though the stream silt is not used as a source of food, a member of the general public could continuously consume food at approximately the levels of cesium-137 found in the silt without exceeding the internal exposure limits recommended by the National Council on Radiation Protection and Measurement.

Laboratory net releases have significantly decreased over the last 5-year period, and the surface water monitoring program confirms that these releases are strictly controlled. It is therefore concluded that the radioactivity in Bull Run silt has an insignificant effect on the environment. Further, there is no evidence of a significant buildup of radioactivity in Bull Run and only background activity is present 1.9 miles from the juncture with the Monongahela River.

Estimates of radiation dose to man

Although the amounts of radioactivity released from the laboratory are small and the results of environmental monitoring show that laboratory operations have had no significant effect on the environment, conservative estimates of the radiation dose to man have been made by analyzing the pathways whereby radioactivity might be transferred from the environment to man. These analyses considered direct exposure, such as by drinking the water in Bull Run and indirect pathways, such as consumption of food. The assumed pathways used in these analyses are hypothetical since the public is not dependent on Bull Run and the laboratory storm drains for food and water. These analyses showed that exposures to man from this radioactivity would be too low to measure and could only be estimated through conservative calculations. Based on the radioactivity released during 1972, the maximum radiation exposure to any member of the general public would be less than 2.6 millirem. This is a small fraction of average annual exposure of 125 millirem to members of the general public from natural radioactivity. The maximum radiation exposure to any member of the general public and the exposure to the population within a 50-mile radius of Bettis are significantly less than 1 percent of the AEC standard. Thus, radioactivity released from Bettis has not caused significant radiation exposure to the general public.

Summary

All potentially radioactive liquid and airborne effluents are filtered and treated prior to release to ensure that all such releases are as low as practicable. The amount of radioactivity released during calendar year 1972 was small and significantly below the AEC standards specified in the applicable regulations.

The quantity of radioactivity released in water during 1972 amounted to a quantity that was not significantly different from the water discharge permit quantity of 0.0011 curie. Since strontium-90 is the predominant and longest-lived radionuclide in the laboratory effluents, the laboratory radioactivity concentration guide is conservatively based on the AEC standard for strontium-90 in water. The average concentration of radioactivity in liquid effluents was only 0.44 percent of the AEC

standards; all liquids were released at concentrations far below the AEC standards. Airborne particulates released to the atmosphere contained less than 0.024 curie and were generally below the sensitivity of the measuring equipment. The airborne particulate radioactivity concentration is less than 5.7 percent of the applicable AEC standard for an unknown mixture of radionuclides in air. Solid radioactive waste materials are shipped in Department of Transportation-approved, sealed containers to an Atomic Energy Commission-approved burial ground. Hence, these waste products have no effect on the quality of the human environment in the communities surrounding the laboratory. All other waste disposal processes are designed to ensure that all such releases from the laboratory are made in accordance with the applicable regulations.

Water quality measurements are made on water samples, which are collected from the small streams on the laboratory site. In addition, analysis of the radioactivity in silt from these streams is also performed. The environmental radiation levels within and at the laboratory boundary are measured by means of thermoluminescent dosimetry monitoring devices. Analyses of these environmental monitoring data indicate that the operation of the laboratory during 1972 did not have any significant effect on the quality of the human environment at the laboratory or surrounding communities.

REFERENCE

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Recent coverage in *Radiation Data and Reports:*

Period	Issue
January–December 1971	March 1973

3. Paducah Plant [5] January–December 1972

Union Carbide Corporation
Paducah, Ky.

The Paducah Gaseous Diffusion Plant (PGDP) is located in McCracken County, Kentucky, about 4 miles south of the Ohio River and 20 miles east of the confluence of the Ohio and Mississippi Rivers. The plant is an AEC-owned, contractor-operated uranium enrichment cascade with associated uranium hexafluoride (UF_6) manufacturing plant and extensive support facilities. The Paducah processing facility now consists of 1812 diffusion stages housed in five buildings with a total ground coverage of about 74 acres. Including support facilities, the plant has a total complement of about 30 permanent buildings.

Except for the large raw water treatment plant, all buildings are within a 750-acre fenced area. A buffer area of at least 1200 feet in depth exists on all sides of the fenced area. Beyond the AEC-owned buffer is an extensive wildlife management area leased or deeded to the Commonwealth of Kentucky. There is no habitation within 3,000 feet of any of the process buildings. The nearest incorporated towns are Metropolis, Ill., located 5 miles to the northeast and LaCenter, Ky., located 11 miles southwest. Paducah, Ky., a city of 35 000, is located 12 miles east of the plant.

The primary plant, the diffusion cascade, contains a physical process in which UF_6 is fed into the system, pumped through the diffusion stages and eventually is removed, still as UF_6. The product is enriched in the fissionable uranium-235 isotope and the "tails" are withdrawn at the bottom as depleted UF_6. The process pumps require electric power, lubrication, and

[5] Summarized from "Environmental Monitoring at Major U.S. Atomic Energy Commission Sites, Paducah Plant, Calendar Year 1972" WASH–1259.

air for cooling. The compressed bases are cooled by a heat exchange fluid, which is in turn cooled by recirculating cooling water.

The basic inputs to the feed manufacturing plant are hydrogen, anhydrous hydrogen fluoride (HF), and uranium oxide (UO_3). The product is uranium hexafluoride (UF_6). Theoretically, 1000 tons of HF are required to convert 2000 tons of uranium from the oxide to UF_6.

Some of the depleted UF_6 from the cascade is reacted with hydrogen to recover HF and to convert the volatile UF_6 to the more easily stored UF_4. In the same facility, the Metals Plant, some of the UF_4 is reduced to metal by reaction with magnesium. The reaction results in the largest volume solid waste product of the plant processes, a magnesium fluoride slag.

Air monitoring

Continuously operating air sampling stations are established on electric power poles at four locations on the perimeter fence and at five locations approximately 1 mile from the plant site. Each sampling station consists of a metal housing sheltering a 2-inch membrane filter holder and containing (as the air flows) a flow meter, a gas scrubber, flow throttling valve, and an air pump. Air flow through the system is adjusted to 0.3 cfm (86 cubic meters per week). The membrane filter is removed each week for long-lived alpha and beta radioactivity determinations.

The gas bubbler is filled to about a 7-inch depth with glass beads to disperse the air in the scrubbing solution of about 1 liter of 0.025 normal sodium hydroxide. This collection technique is essentially 100 percent efficient for HF collection in the parts per billion range. The fluoride content is determined by the specific ion electrode method. Results of the environmental air sampling program are shown in table 21.

Alpha radioactivity attributed to uranium from the plant averaged less than the minimum detectable level at the outer edge of the buffer zone. The samplers on the north and east perimeter fences, which are nearest the Feed Plant and the Metals Plant, collected detectable amounts. Beta radioactivity levels at all stations and in all samples were far below the applicable concentration guide.

All gas scrubber samples collected offsite over weeklong periods and analyzed for fluorides were within the Kentucky ambient air stand-

Table 21. Environmental air sampling results, Paducah Plant, January-December 1972

Sample point [a]	Number of samples	Alpha radioactivity concentration (fCi/m³)			Percent of AEC standard	Beta radioactivity concentration (pCi/m³)			Percent of AEC standard
		Maximum	Minimum	Average [b]		Maximum	Minimum	Average [b]	
At plant perimeter fence:									
North	52	480	<20	<30±20	(c)	11	<0.1	<2.4±0.68	(c)
East	52	540	<20	<30±21	(c)	3.9	<.1	<.8± .22	(c)
South	52	20	<20	<20±10	(c)	1.2	<.1	<.3± .07	(c)
West	52	30	<20	<20±20	(c)	1.9	<.1	<.5± .14	(c)
1 mile outside plant perimeter fence:									
North	52	30	<20	<20±10	[d] <1	1.1	<.1	<0.3± .03	[e] <0.03
East	52	20	<20	<20±10	<1	.5	<.1	<.2± .06	<.02
Southeast	52	40	<20	<20±10	<1	.5	<.1	<.2± .03	<.02
South	52	20	<20	<20±10	<1	.6	<.1	<.2± .03	<.02
West	52	30	<20	<20±10	<1	.4	<.1	<.2± .03	<.02

[a] See figure 6.
[b] The plus-or-minus (±) values represent the 95-percent confidence limits. The 95-percent confidence limit is calculated from the standard deviation of the average, assuming a normal frequency distribution, and is a measure of the variability in the range of concentrations measured. It does not represent the conventional error in the average of repeated measurements on identical samples. Data which are below the minimum detectable limit are expressed as less than (<) the minimum detectable value. In computing average values, sample results below the detection limit are assigned the detection limit value with the resulting average value being expressed as less than (<) the computed average value.
[c] Environmental standards not applicable.
[d] The AEC standard for natural uranium is 2 pCi/m³.
[e] The AEC standard for thorium-234 is 1 000 pCi/m³.

Table 22. Uranium concentrations in environmental water samples, Paducah Plant, January-December 1972

Sample point [a]	Number of samples	Uranium (mg/liter)				
		Maximum	Minimum	Average	Standard	Percent of standard
Ohio River:						
9	11	0.008	0.001	0.003 ± 0.0014	[b] 0.009	33
50, 51, 52, 53 composite	11	.011	.001	.002 ± .0018	[b] .009	22
Big Bayou: [c]						
1	12	.008	.001	.002 ± .0012	[d] 60	0.003
3	52	.052	.001	.015 ± .0033	[d] 60	.03
Mouth of creek:						
21	11	.110	.001	.021 ± .033	[e] 60	.04
Little Bayou: [f]						
17	52	2.22	.019	.441 ± .130	[d] 60	.7
Ground water: [c]						
11	12	.004	.001	.001 ± .0006	[d] 60	.002
12	12	.007	.001	.002 ± .0012	[d] 60	.003

[a] See figure 6.
[b] Kentucky Water Pollution Control Commission regulation WP-4-1 (*14*).
[c] Unclassified.
[d] AEC concentration guide equivalent for natural uranium.
[e] Ohio River Valley Sanitation Commission Pollution Control Standard 70-1 (standard for thorium-234)(*15*).
[f] Unclassified stream on government property.

ard. The average results were about 20 percent of the standard.

Water monitoring

Water samples are collected continuously in the Big Bayou and in the Little Bayou (essentially a drainage ditch traversing AEC and TVA property). Grab samples are taken each month from several locations in the Ohio River, at the mouth of the Bayous, and from two test wells. The effluent from the sewage disposal plant is sampled for weekly determinations of suspended solids.

The extensive water sampling and analyses showed no increase in concentrations of the parameters of interest in either the Ohio River or in ground water (tables 22–23). The concentrations of uranium and beta radioactivity in the Big Bayou and at the mouth of the creek were well within the Ohio River Valley Water Sanitation Commission and AEC limits.

Soil monitoring

Soil samples were collected from near the north, east, south, and west AEC property boundaries. Plugs of soil 3½ inches in diameter were removed from the ground down to a uniform depth of 4 inches, dried, pulverized, and blended before analysis. Duplicate aliquots were spiked with uranium-233 and the uranium was quantitatively removed and analyzed by mass spectrometry. The results (table 24) ranged from 1.1 ppm to 2.0 ppm. Background in this area was determined in prior years to be 0.9 ppm. None of these concentrations would be expected to have a significant impact on the environment.

Table 24. Concentrations of uranium in soil, Paducah Plant, January-December 1972

Sample point	Concentration (μg/g)
At AEC property boundary:	
North	2.0
East	1.1
South	2.0
West	1.2
Background sample taken in 1971, 12 miles from plant	0.9

Summary

Air, water, and soil in the vicinity of the Paducah Gaseous Diffusion Plant were continu-

Table 23. Beta emitter concentrations in environmental water samples, Paducah Plant, January-December 1972

Sample point [a]	Dissolved (pCi/liter)					Suspended (pCi/liter)				
	Number of samples	Maximum	Minimum	Average	Standard	Percent of standard	Number of samples	Maximum	Minimum	Average	Standard	Percent of standard
Ohio River:												
9	11	36	<4.5	<8.1 ± 6.4	[b] 1 000	<0.81	8	<4.5	<4.5	<4.5 (lower limit)	[b] 1 000	<0.45
50, 51, 52, 53 composite	11	45	<4.5	<17 ± 13	[b] 1 000	<1.70	8	41	<4.5	<12.4 ± 12	[b] 1 000	<1.2
Big Bayou: [c]												
1	12	248	<4.5	<50 ± 39	[d] 20 000	< .25	9	167	<4.5	<33 ± 26	[d] 20 000	<.17
3	52	834	<4.5	<39 ± 14	[d] 20 000	< .20	39	567	<4.5	<90 ± 40	[d] 20 000	<.45
Mouth of creek:												
21	11	1 782	<4.5	<231 ±321	[e] 20 000	<1.16	8	108	<4.5	<39.4 ± 29.7	[e] 20 000	<.20
Little Bayou: [f]												
17	52	11 232	41	1 228 ±452	[d] 20 000	6.14	39	3 276	50	538 ±196	[d] 20 000	2.69
Ground water: [c]												
11	12	41	<4.5	<9.9 ± 6.5	[d] 20 000	<.05	9	63	<4.5	<21 ± 15	[d] 20 000	<.11
12	12	45	<4.5	<12 ± 5.0	[d] 20 000	<.06	9	18	<4.5	<4.8 ± 3.8	[d] 20 000	<.02

[a] See figure 6.
[b] Kentucky Water Pollution Control Commission regulation WP-4-1 (*14*).
[c] Unclassified.
[d] AEC concentration guide equivalent (thorium-234).
[e] Ohio River Valley Sanitation Commission Pollution Control Standard 70-1 (standard for thorium-234) (*15*).
[f] Unclassified stream on Government property.

ously or periodically sampled during 1972 at the locations shown on figure 6. Analyses for materials known to be in plant effluents were made to provide effluent control information and to determine compliance with applicable air and water quality standards.

The air analyses for radioactivity indicate concentrations at all offsite sampling stations averaged less than 1 percent of the applicable AEC standards.[1]

Soil samples collected to provide historical background data were analyzed for uranium. The results ranged from 1.1 ppm to 2.0 ppm at the AEC property boundary. None of these concentrations would be expected to have a significant impact on the environment.

There was no detectable change in radioactive characteristics of either the Ohio River or ground water attributable to Paducah Gaseous Diffusion Plant operations.

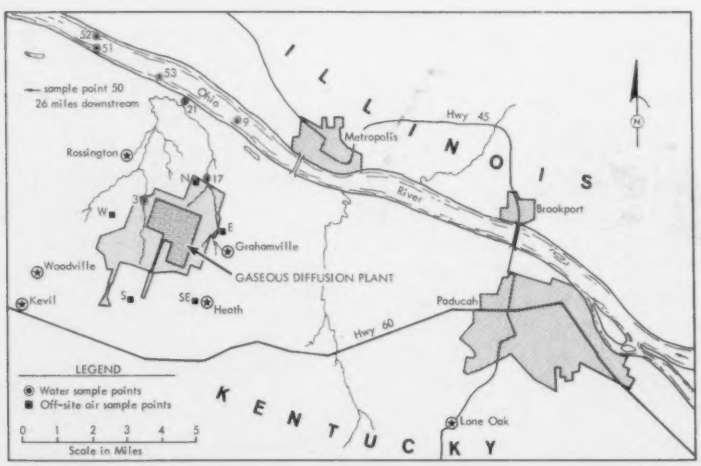

Figure 6. Sampling locations, Paducah Gaseous Diffusion Plant

REFERENCES

(14) KENTUCKY WATER POLLUTION CONTROL COMMISSION. Kentucky Water Pollution Control Commission regulation WP–4–1.
(15) OHIO RIVER VALLEY WATER SANITATION COMMISSION. Ohio River Valley Water Sanitation Commission (ORSANCO), Pollution control standard number 70–1.

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1971	July 1973

Reported Nuclear Detonations, July 1974

(Includes seismic signals presumably from foreign nuclear detonations)

The U.S. Atomic Energy Commission announced a nuclear test in the yield range between 20 and 200 kilotons was conducted underground July 10, 1974 by the Atomic Energy Commission at its Nevada Test Site.

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CALCULATIONS OF DOSES, POPULATION DOSES AND POTENTIAL HEALTH EFFECTS DUE TO ATMOSPHERIC RELEASES OF RADIONUCLIDES FROM U.S. NUCLEAR POWER REACTORS IN 1972. *Office of Radiation Programs, Environmental Protection Agency. Radiation Data and Reports, Vol. 15,* August 1974, pp. 477–482.

Atmospheric emissions of radionuclides during 1972 reported by operators of 14 boiling water nuclear power reactors and 2 pressurized water nuclear power reactors in the United States were analyzed to calculate resulting doses in the general offsite environment. A sector-averaged diffusion equation, using facility generated onsite annual average meteorology, was used to propagate the emissions from the release point out to 81 kilometers. In 1972, 4.88 megacuries of radioactivity were released to the atmosphere from 16 reactors on 13 sites. The resulting whole body population dose was calculated to be 1649 person-rem to a population of 29.2 million people. The potential health effects induced by external radiation from nuclear power plant emissions in 1972 were less than those induced by natural background and occupational radiation exposures.

KEYWORDS: Atmospheric radioactive releases, health effects, population doses, 1972, nuclear power reactors, United States.

RADIOACTIVITY IN BRAZILIAN MINERAL WATERS. *P. L. Hainberger S.J., I. R. de Oliveira Paiva, H. A. Salles Andrade, G. Zundel,* and *T. L. Cullen. Radiation Data and Reports, Vol. 15,* August 1974, pp. 483–488.

Samples of mineral waters from various parts of Brazil were analyzed for their radium content. Radium-226 activity ranged from nondetectable to 94.1 pCi/liter, and radium-228 ranged from nondetectable to 152 pCi/liter.

KEYWORDS: Brazil, radium-226, radium-228, mineral water.

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